RECOGNISING ACHIEVEMENT

GCE

Physics A

Advanced GCE **7883**

Advanced Subsidiary GCE **3883**

Report on the Units

June 2008

3883/7883/MS/R/08

OCR (Oxford, Cambridge and RSA Examinations) is a unitary awarding body, established by the University of Cambridge Local Examinations Syndicate and the RSA Examinations Board in January 1998. OCR provides a full range of GCSE, A level, GNVQ, Key Skills and other qualifications for schools and colleges in the United Kingdom, including those previously provided by MEG and OCEAC. It is also responsible for developing new syllabuses to meet national requirements and the needs of students and teachers.

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

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

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

Any enquiries about publications should be addressed to:

OCR Publications
PO Box 5050
Annesley
NOTTINGHAM
NG15 0DL

Telephone: 0870 770 6622
Facsimile: 01223 552610
E-mail: publications@ocr.org.uk

CONTENTS

GCE Physics A (7883)

Advanced Subsidiary GCE Physics (3883)

REPORTS ON THE UNITS

Unit/Content	Page
2821 Forces and Motion	1
2822 Electrons and Photons	4
2823/01 Wave Properties	7
2823/02 & 2826/02 Principal Moderator’s Report	8
2823/03 Practical Examination 1	10
2824 Forces, Fields and Energy (Written Examination)	14
2825/01: Cosmology	17
2825/02 Health Physics	21
2825/03 Materials	23
2825/04 Nuclear and Particle Physics	26
2825 / 05A2 Physics Option Telecommunications	32
2826/01 Unifying Concepts in Physics	36
2826/03 Physics Practical	38
Grade Thresholds	41

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 questions and mark scheme allowed those whose responses indicated a good level of understanding to achieve very good marks. At the same time the well taught, average candidate was able to demonstrate a pleasing standard. 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 with approximately 9% scoring less than 10 and just over 4% scoring more than 50. This suggests that the paper contained sufficient material to test the most able candidate. There were a significant number of candidates (30%) with a mark of less than 20 and there appeared to be little evidence of the course being thoroughly taught in these cases. Those candidates with less than 20 were often unable to give acceptable definitions, used inappropriate formulae in their calculations and often left complete sections of questions blank.

Questions 2, 5 and 6 were the main questions that had sections that were left blank and candidates from some centres seemed completely unprepared for such questions. The mean mark for candidates in this session was 27.8, which was almost 5 marks less than the mean mark of 32.4 obtained in the June session in 2007. All the questions 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. However, there were parts of question one and question five that proved difficult for all but the very able candidate. The responses differed widely depending on 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, poor presentation of mathematical analysis and the failure to read the question carefully reduced the marks of many candidates of the full range of abilities. However, the majority of candidates were able to give good answers to some parts of every question.

The first parts of question one allowed a good proportion of the candidates to get off to a good start with the paper. The most able candidates scored highly in all the questions. The written explanations in question six were often of a poor standard by candidates of all abilities. The standard of written communication was generally adequate with many candidates scoring at least one of the marks available for written communication.

Comments on Individual Questions

Question one

Q.1 The majority of candidates were able to score at least half marks on this question. In part (a)(i) over 90% of candidates scored full marks on this part of the question. However, in part (ii) at least half of the candidates spoilt their answer by including a scalar with their correct vectors. Kinetic energy and power were the two most common wrong answers with weight the most common vector omission. In part (b) (i) over 90% were able to show the given value for the vertical component but less than half were then able to use this value to calculate the time to reach the maximum height. More than a quarter used the velocity of the ball rather than the vertical component of the velocity. The horizontal distance proved to be even more difficult for the vast majority of candidates. More than 60% used an equation of motion assuming an acceleration of 9.8 m s^{-2} in the horizontal direction. Only the very able scored marks in part (b)(ii). The graph for the vertical component of velocity was often drawn as sine or cosine curve with many starting their graph from the origin. The graph of distance against time was very often drawn as a straight line. It was very disappointing that more than 60% failed to score any marks in (b)(ii). There was a good range of marks in (b)(iii) with more than 50% scoring 3 or 4 marks. The average candidate was able to describe the correct energy changes as the ball travelled from the ground to its maximum height. However, many then went on to say that the ball had zero kinetic energy at its maximum height. A significant minority thought that the ball started with potential energy that was converted to kinetic energy at A and then suddenly converted to potential energy at H. These candidates did not suggest that the transition was a gradual change as the ball gained height. Some candidates failed to score as they referred to the kinetic energy as if energy was a vector having vertical and horizontal components. More than 75% scored the QWC mark but there were a significant number who wrote eight lines or more but in only one sentence.

Question two

In part (a) the definitions were poorly stated by 45% of candidates with only 20% able to give both of the correct statements for the conditions for equilibrium. The majority lost marks due to imprecise statements. Comments such as all the forces must be zero and upward forces equal downward forces are not acceptable at this level. The <u>sum</u> of the anticlockwise moments equalling the <u>sum</u> of the clockwise moments or the resultant torque is zero were statements that were often omitted by candidates. In the moment of a force the <u>perpendicular</u> distance to the <u>pivot</u> was required and poor imprecise statements cost candidates a mark in this part. Approximately 40% were able to solve the calculation of the tension in part (b). A large number of candidates spent time trying to calculate the distance along the beam to point A rather than use the perpendicular distance from the force to the pivot. If the candidates had known the definition of moment of a force then maybe they would have been able to make the correct application to this situation. The last part of (b) was only answered well by the very able. The diagram shows only three forces acting on the beam. Candidates were expected to see that the beam could not be in equilibrium without another force acting.

Question three

This question provided good differentiation. The answers to part (a) were generally very good with more than 80% obtaining the correct value for the mass. Over 60% were able to complete the calculation of the pressure. There were a number of candidates (about 10%) who knew the expression for density but were unable to rearrange the equation to obtain the mass. There were more candidates who did not know the expression for pressure and many used mass / area.

Question four

This question produced good differentiation with over 20% scoring full marks and over 30% scoring four. In part (a) the correct calculation of the force F was seen more often than in the past with similar questions. However, there are a large number of candidates who cannot take the forces given and draw them in order and in the same direction to produce a triangle of forces. The good candidates were able to resolve forces and obtain a solution in a few lines. The candidates who tried to analyse their triangle using trig generally made an error and failed to obtain a correct value for F. In part (b) almost all the candidates gained one mark for suggesting what could be done to produce more damage to the wall but only 30% were able to explain why their suggestion would cause more damage.

Question five

This question produced good differentiation but there were many low scores and few very high scores. More than 50% obtained tree or less and slightly more than 25% scored 5 or more. Part (a) was generally well answered but those who found trigonometry difficult were unable to produce a satisfactory method of determining the given value. Part (b) was poorly done with a minority using the resistive force to calculate the work done against this force. A large number of candidates used the weight of the lorry to determine this work done. In part (c) the power needed by the lorry was poorly calculated with the answer obtained for part (b) often being repeated here. Candidates did score a mark for the expression for power in terms of work done / time or force x velocity. Able candidates who had been unable to calculate answers for previous parts were more successful in part (d). The calculation of the height gained per second was often completed successfully and then this led to the correct answer. Very few candidates spotted that the gain in potential energy per second was equal to part (c) minus part (b). Surprisingly a significant number of candidates were unable to give a correct unit for power. Fewer than 20% gave a correct statement for part (e). The part played by the component of the weight down the slope in braking was seldom clearly explained and the majority just stated that the resistive forces would be greater on the slope.

Question six

In this question there was an almost equal spread of marks. The question differentiated well and over 50% scored between 4 and 10 marks. In part (a)(i) there were nearly 45% of candidates with full marks. Only 10% failed to score any marks. The majority of lost marks were for not converting the extension given in mm on the graph into m or reading the extension for a force of 90 N where the graph is no longer straight and the expression for Young's modulus does not apply. The weaker candidates did not know the correct formula or confused the expressions for stress and strain. Part (a)(ii) was only completed correctly by the more able candidate (about 25%) with many calculating the strain or using force x extension. The power unit error in the extension also appeared here but was only penalised once in the question. In part (b) a significant number of candidates thought that the wire remained at its extended length ('the extension remains the same') when the force was removed and about half gave an acceptable answer. In part (c) the answers seemed to be dependent on the amount of coverage this topic had received by the candidate. There was a full range of marks but disappointingly only 12% obtained 5 or 6 marks and over 25% scored zero. Many of the latter left this whole section blank. There were far too many poor descriptions that did not answer the question. The use of the terms ductile and brittle to describe the copper wire and glass fibre respectively was given only by the good candidate. Those who gave sketch graphs usually gained more marks. The explanations were often helped by a clearly labelled graph.
In general candidates lost a large number of marks through poor explanations.

2822 Electrons and Photons

General comments

The overall performance of the candidates was broadly similar to last session. There was however, an increase in the number of poorly prepared candidates scoring less than a third of the marks. As with previous years, there remains a wide disparity between Centres. Some Centres had made excellent use of past papers in the preparation of the candidates; this was particularly noticeable in the questions on quantum physics. The paper required sketches of either circuits or circuit symbols; the lack of competence in this area is a cause for concern. A very small number of candidates drew the correct symbol for the light-dependent resistor or had the skill to construct a potential divider circuit. There was also a slight decline in the quality of presentation of analytical answers. The main hurdles for most candidates remain powers of ten and rearranging equations.

The quality of written work has shown a sharp decrease. In some cases, the candidates' scripts were almost illegible, with letters and numbers merging into random doodles. There is also no excuse for candidates not being able to correctly spell words such as 'ammeter' and 'parallel' after one year of AS physics. The poor writing skills were more noticeable this year because examiners were marking scanned scripts electronically. For future reference, candidates are reminded to keep their written work within the scanned regions of the paper.

Most candidates finished the paper in the scheduled time.

Comments on Individual Questions

Question One

Most candidates had serious problems recalling basic definitions. The modal score for this opening question was three.

Most candidates in **(a)** recognised that the directions of conventional and electron flow were 'opposite'. In spite of the command word 'state', too many candidates gave lengthy answers.

The answers to **(b)** were very disappointing. The most popular answer was that potential difference is '*the product of current and resistance*'. Very few candidates defined potential difference as '*energy transfer per unit charge*'. Candidates have an extremely poor comprehension of this important electrical quantity.

Less than half of the candidates managed to get a mark in **(c)(i)** for the definition of the kilowatt-hour. A disappointing number of candidates confused this quantity with power. In addition to this, a disturbing number of candidates thought the definition for the kilowatt-hour was 'kW h = power in kW $\times$ time in hours'.

Most candidates did manage to get the correct answer for the cost of £243 in **(c)(ii)**. Inevitably, some candidates decided to multiply all the numbers given in the question and got an answer that was greater by a factor of 10^5. Such candidates were not perturbed by costs of about 24 million pounds for operating the kettle.

Question two

The majority of the candidates found this question accessible especially **(a)**. Candidates demonstrated a good knowledge of both series and parallel circuits and most realised which combination produced maximum and minimum resistances.

Most candidates drew good sketches of a series circuit in **(a)(i)** and then correctly determined the total resistance of 44 Ω. A small number of candidates shorted out their resistors; on this occasion, examiners decided to be generous with the marking.

The majority of candidates provided suitable sketches for the parallel circuit and correctly determined the minimum resistance in **(a)(ii)**. A small number of candidates got the combinations reversed. A significant number of candidates struggled with reciprocals. The most frequent wrong answer was 0.23 Ω and a disturbing number of candidates opted for the erroneous equation $R = \dfrac{R_1R_2R_3}{R_1 + R_2 + R_3}$.

In **(b)**, candidates found it easier to cope with changes in length than changes in diameter and very few managed to complete table of resistances successfully. Fortunately, many candidates managed to secure two marks through the error carried forward; the common wrong answers were 108/18/90 or 108/72/360 or 108/144/720.

Question three

Candidates generally coped with the characteristics of the thermistor and the LDR. However, the quality of written work and use of technical vocabulary remains a cause for concern.

Candidates generally gave adequate descriptions of the variation of resistance for the thermistor and the LDR in **(a)(i)** and **(ii)**, but the sketches for the circuit symbols were poor. It is difficult to fathom how candidates can be so incompetent in drawing symbols and circuit diagrams. Too many candidates produced a variety of bizarre symbols for the LDR. Some resembled light-emitting diodes. Very few candidates managed to get the correct number of two arrows for the LDR symbol. The potential divider sketches for **(a)(iii)** were very disappointing. For many candidates, a potential divider meant a light-dependent resistor connected directly to a supply. Some candidates drew a general potential divider circuit with fixed or variable resistors. There were also too many circuits with either the power supply or the voltmeter omitted.

The answers to **(b)(i)** were extremely disappointing. Most candidates drew a straight line or a curve passing the origin. It never occurred to them that the metal conductor cannot have zero resistance at 0^0 C. Most candidates struggled with the description of the experiment in **(b)(ii)**. A disappointing number of candidates gave a good description of an experiment involving a thermistor; they scored poorly because the question was not answered. Almost all candidates failed to mention how they changed the temperature of the wire. There was no indication in their description of a water bath or a hot plate. A disappointing number of candidates thought that they could heat the wire by increasing the current and the temperature of the wire could be measured with a thermometer held on the wire. Candidates are reminded to scrutinise a question with care and perhaps do some brief planning before putting their thoughts on paper. The modal mark for QWC was two.

Question four

Most candidates managed to show the resistance of a single wire to be 53 Ω in **(a)(i)** . A few candidates used $A = 2\pi r$ and then tried to fiddle their answers. Some candidates lost a mark for prematurely rounding their value for the cross-sectional area to 3×10^{-9} m^2. A good number of candidates provided an adequate answer for **(a)(ii)**. A small number of candidates recalculated the resistance using a cross-sectional area that was a factor of 26 times greater that that for a single wire. The most elegant answers were often brief, such as '*the* 26 *wires are in parallel'* or '*the resistance must be* 53/26 = 2 Ω'.

A pleasing number of candidates either used $P = V^2 / R$ or $P = VI$ and $V = IR$ to determine the resistance of the lamp. Very few candidates gave a correct reason for the e.m.f. of the supply being greater than 6.0 V in **(b)(ii)**. Far too many candidates thought that the e.m.f. was greater '*because of lost volts in the supply*', in spite of being told the supply has negligible internal resistance. Some candidates realised the resistance of the cables had something to do with answer. Examiners were specifically looking for a connection between the resistance of the cables and the p.d. across them or the energy lost within the cables. A significant number of candidates were baffled by **(b)(iii)**. Many thought that the 24 W applied to the whole circuit. Such candidates correctly determined the total resistance of the circuit to be 5.5 Ω but then used $V^2 = 24 \times 5.5$ to deduce the e.m.f. of the supply – this gave an incorrect answer of 11.5 V. High-scoring candidates produced immaculate answers and arrived at the correct answer of 22 V in a variety of ways.

Question five

Most candidates demonstrated a good understanding of magnetic fields and magnetic flux density.
Most candidates picked up two marks for their definition of magnetic flux density in **(a)**. A small number of candidates failed to recall the equation for the flux density; the most frequent wrong equation was $B = FIL$.
The majority of candidates correctly drew an arrow pointing to the left for **(b)(i)**. Inevitably, there were also arrows drawn in all possible orientations too. As expected, some candidates failed to spot the 10^{-5} factor on the flux density axis for **(b)(ii)**. Most candidates presented a well constructed answer for the force on the wire. However, a disappointing number of candidates gave the wrong unit for force, used the separation of 3.0 cm for the length of the wire or misread the graph. Candidates should not be struggling with reading values from graphs at this level.

Question six

The world of quantum physics continues to baffle a significant population of the candidates.
A pleasing number of Centres have done a good job looking through past papers and hence **(a)** was not a surprise for their students. Most candidates realised that the electrons were diffracted by graphite. What was the cause for this diffraction remains a mystery for many candidates. Some thought that the diffraction was '*due to holes in the graphite*'. A significant number of candidates thought that the rings were due to the '*diffraction of light*'. Only a small number of candidates understood the role of the atoms or the spacing between the atomic planes and their connection to the de Broglie wavelength of the electrons.
Most candidates correctly estimated the wavelength of X-rays in **(b)(i)**. Many candidates started well with the de Broglie equation in **(b)(ii)**, but then spoilt their answers because of poor rearranging or problems with powers of ten. Some candidates went off the tracks by substituting the speed of light for *v* in the equation $\lambda = h / mv$ and then ended up with a value of 3×10^8 m s^{-1} for the speed of the electrons.

Question seven

This question on the photoelectric effect provided a decent platform for high-scoring candidates to shine.
A pleasing number of candidates realised that **(a)** required an understanding of $Q = It$ and an awareness of the charge on an electron. A good number of candidates secured a mark for jotting down the current of 4.2×10^{-9} A. Many candidates tried using $E = hf$ or $P = VI$ to fiddle their way to the answer of 2.6×10^{10} s^{-1}.
A good number of candidates produced correct answers for **(b)**, with a minority clearly presenting their answers. In some cases, candidates secured a mark for either the photoelectric equation or changing the 2.2 eV into joules. A disappointing number of candidates tried using the value of 2.6×10^{10} from **(a)** as the value for frequency. In most cases, there was a lack of logical organisation.
Most candidates were mystified by **(c)**. The written answers demonstrated a poor understanding of the photoelectric effect and the quantum nature of electromagnetic waves. In **(c)(i)**, some candidates confused the term intensity with frequency. In **(c)(ii)** very few candidates appreciated that the current was directly proportional to the intensity and intensity was related to the rate at which photons were incident on the cathode.

2823/01 Wave Properties

General Comments
The general standard of work was slightly better than last year with the majority of candidates scoring more than 60%. However there were still a significant number of very weak scripts that obtained less than 10 marks. 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

Question 1
Q1. This was generally well answered by the majority of candidates but some carelessly lost marks in the opening part by failing to define the symbols in their chosen equation for defining the refractive index of a material. Most scored full marks for the calculations of the speed of light in the liquid and the angle of refraction.

Question 2
Q2. The concepts of critical angle and total internal refraction are well understood by most candidates but an easy mark was lost by some who failed to mention that the light must be travelling from a dense to a less dense medium. The majority scored full marks for correctly using the formula n=1/sinC in part (b). Part (c) attracted some very good answers with many candidates able to show a detailed understanding of multipath dispersion and how it may be reduced.

Question 3
Q3. This was a straightforward question for most but surprisingly a significant number were unable to state three phenomena that apply to both transverse and longitudinal waves. Many scored full marks for drawing the correct CRO trace using the data provided but very few scored the mark for (c) (iii) that asked how the trace will change when the time base setting is changed from 1ms cm-1 to 10 ms cm-1. The vast majority correctly calculated the wavelength of the sound.

Question 4
Q4. This proved to be the most difficult question on the paper. Many offered vague explanations of the principle of superposition and less than half the candidates scored more than 1 mark for part (b) which required an understanding of the concept of path difference. Many scored at least 4 of the 6 marks available for the description of the Young's double-slit experiment. Some good candidates lost marks by failing to state the measurements to be taken as asked for in the question.

Question 5
Q5. Many found this very easy and scored full marks but there was a significant number who were clearly guessing at the answers suggesting that it may not have been taught to them.

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

General Comment

This is the penultimate year of this specification and there has been a 10% increase in the number of candidates taking AS coursework and about an 8% increase in those taking A2. The number taking the coursework route represents about a third of the total taking the examination. Perhaps, because some centres were new to the specification, there has been an increase in rather poor administration, with missing assessment and authentication forms.

In some cases, centres failed to double the marks before entering on the MS1. I am sad to report that there has been an increase in the number of centres failing to award marks in accordance with the hierarchical structure of the scheme, where both descriptors are needed for the award of a mark, and where intermediate marks can only be gained by agreement with one or other of the higher descriptors, or partial agreement with both, e.g. with A5a and A5b awarded and A7a agreed the mark should be 6.

Having started off rather negatively, it was pleasing to see the vast range of investigations undertaken and the really excellent work achieved by the majority of centres. The mark range is very similar to previous years and compares well with the practical examination route through this specification. Both routes offer benefits and disadvantages to the candidates taking them.

The last major award at AS gives pass rates and grade boundaries remarkably similar to previous years and still exactly at the designed grade thresholds originally proposed many years ago.

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 given the top mark should be supported by annotation showing exactly why the marker felt if 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. I look forward to continued good practice in the final major year of this specification.

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 had 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. Sadly there were one or two Centres where inappropriate help was given; it is essential that Supervisors read the instructions carefully. There were also a few cases where candidates had not been properly supervised on the planning exercise; the candidates concerned were reported for malpractice.

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 strain gauge attached to a piece of wood varies with the temperature of the wood.

The majority of the plans were about an appropriate length. This summer part **(c)** asked for the range and precision of any instruments that would be used and part **(d)** asked for the factors that needed to be controlled – plans often omitted these parts.

Candidates were expected to draw a workable diagram of the apparatus which included a strain gauge attached to a piece of wood and a method of measuring temperature. It was also expected that candidates should draw a correct circuit diagram using appropriate symbols; surprisingly this mark was still not scored as often as examiners would have expected. Candidates were also expected to explain their procedure. Some weak candidates suggested different experiments. Additional marks were scored for a suitable method of changing the temperature (freezer, kiln, oven, etc.) and the use of a suitable adhesive to fix the strain gauge to the wood. Few candidates discussed waiting for the temperature of the wood to stabilise.

Candidates often did not suggest factors that needed to be controlled. In this experiment the obvious factor to keep constant was the humidity which was mentioned in the stem of the question. Additional detail marks could have been scored for the method of checking humidity.

There was one mark available for a relevant safety precaution. Again too often examiners just see a list of standard laboratory safety rules rather than an explanation as to why a safety precaution is required in this particular experiment. In this case it was expected that reference would be made to the use of the glue and/or hot and cold surfaces.

There were four marks available for extra detail e.g.

Typical resistances of a strain gauge
Determination of ammeter range or ohmmeter range.
Method of checking humidity (humidity sensor or hygrometer).
Discussion of strain along and across the grain.
Discussion of temperature compensation (including self compensation).
Discussion of choice of glue to avoid differential expansion.
Method of determining resistance for bridge methods.
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 an unknown mass can be balanced on a metre rule using a known mass.

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

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. Common errors in this part were to have inconsistent readings (distances not measured to the nearest millimetre) or not to use a suitable range for Q.

Graphical work was generally done well. Weaker candidates often used either less than half of the graph grid for their points. Points were usually plotted accurately to the nearest half square. Often 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 six very 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 y-intercept 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 $y = mx + c$. Too often a false origin was used and this resulted in an incorrect y-intercept.

In part **(f)** candidates were asked to determine values for *Q* and *R*. Again weak candidates do not use their answers for the gradient and *y*-intercept; failure to use these values prevented candidates gaining four marks. Good candidates equated the gradient to *Q*/*M* and the *y*-intercept to 0.20*R*/*M*. Determining the unit for *Q* proved difficult for a number of candidates with common errors quoted as 'N' or 'kg m^{-1}'

Part **(g) (i)** asked candidates to determine the percentage difference between two values of *R* and then in **(g) (ii)** explain whether their results indicated random and/or systematic errors. Weak candidates found determining the percentage difference difficult often not finding a difference. Part **(g) (ii)** was very poorly answered. Candidates often failed to refer to their results often just describing errors which might have occurred in their practical work or differences in their values of *R*. Examiners expected the scatter of points on their graph would help candidates explain the whether random error existed and some reference to the percentage difference would explain whether there was a systematic error. Candidates were expected to give an appropriate conclusion. Too often candidates answers lacked clarity and thus did not score marks.

2 In this question candidates were required to investigate how cross-sectional area affects how quickly the amplitude of an oscillating system decreases and then write an evaluation of the procedure.

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

The determination of the percentage uncertainty was better this year with most candidates using the correct ratio. Many candidates did not use an appropriate absolute uncertainty of 0.1 cm. In part **(b) (ii)** the question was written so as to encourage candidates to add the two percentage uncertainties already; sadly too many candidates multiplied their previous answers.

In part **(e)** it was expected that candidates would gain a larger value for *t*. There was evidence that many weaker candidates were unable to read a stop watch correctly.

In part **(f)** candidates were asked whether their results supported the relationship that *t* is inversely proportional to *A*, explaining their reasoning clearly. No marks were awarded without reasoning. Weak candidates were either very vague with their reasoning or confused inverse proportionality with direct proportionality. 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 **(g)** 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 releasing bob and starting the timing simultaneously,
Difficultly in knowing when to stop timing or difficulty in judging amplitude,
Oscillations not always in a vertical plane
Time taken was too short
two readings of t and A are not enough to verify the suggestion.

Credit worthy solutions:
Release bob from larger amplitude and start timing when amplitude is 6 cm,
Use of reference mark/slow motion video playback
Repeat readings and find an average
Use longer string or smaller areas of card
Use many different areas <u>and</u> plot a graph relating t v A or t v $1/A$.

Some candidates discussed ideas such as “the paper not been square” or “the scissors were not sharp enough.”

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

Candidates appeared to have no difficulty in completing the paper and almost all attempted all of the questions very fully. Most wrote a full answer to the last question, even if an incorrect one. The paper appeared to be more demanding than in the last few sessions. No question or part of question was inaccessible to the candidates but the combination of topics led to a lower total for the whole paper. Candidates showed significant knowledge of some topics and little of others. The most successfully answered questions by all candidates were Q4 and Q7. The questions which proved most difficult were Q1 (a) and Q6 (a) (ii) where many candidates of all abilities showed little knowledge or understanding. This did not impede them from answering the rest of the question successfully in each case. There were also fewer good answers to the gravity and circular motion question, Q3, than expected. In the questions written in the form 'show that…' candidates are still not showing all the steps in any calculations, leaving out the step between a mathematical equation and the rounded answer given in the question. It is vital that candidates show that they have completed this calculation.

Comments on Individual Questions

Q1 (a) Most candidates did not understand about the forces between the cubes and so failed to progress correctly beyond (ii). However no one was put off by this question and happily gave an answer in each space.

(b) Writing down the equations in terms of the symbols given proved to be a more demanding task than expected and less than 70 % gained both marks. Some ruined their answers by writing in terms of m_1 and m_2 instead of m.

(c) Most appreciated that momentum and/or kinetic energy were conserved in the interaction but some failed to explain how cube 2 was involved in the transfer. Any sensible answers gained credit in part (ii). The popular incorrect description had cube 1 stationary and cubes 2 and 3 moving at half of the incident velocity. This conserves momentum but not kinetic energy and scored one out of the two marks

Q2 (a) Almost all candidates could calculate the frequency correctly using data from the graph.

(b) Candidates were expected to estimate the maximum gradient of the graph which many did successfully. Some knew how to relate the maximum velocity to the maximum acceleration. Use of the formula $a = (2\pi f)^2x$ and the value of x from part (c) was only permitted if a different method was used to find x, e.g. the area under the first quadrant of the graph of the relationship between maximum displacement and velocity. Candidates who gave no indication on fig.2.2 as to how they obtained the gradient did not score any marks.

(c) The most popular method was to estimate the area under the graph, otherwise candidates used one of the formulae quoted above.

(d) Few candidates had any idea about how the kinetic energy of the glider varied with time. Most drew a sinusoidal wave with both positive and negative energies. Most of the minority who realised that the energy could only be positive drew a graph with cusps rather than a sinusoidal variation.

Q3 (a) Most candidates were able to define gravitational field strength.
Far fewer appeared to be quoting the expression for the gravitational field of a point mass.

(b) Those who based their answer on Newton's Second law explained successfully why the acceleration due to gravity and the gravitational field strength have the same value. Other approaches often did not make any specific point worthy of a mark.

(c) Most candidates remembered to convert kilometres into metres, possibly because otherwise the answer for the speed of the space probe would have been so small. However a significant number calculated either r/t or $\pi r^2/t$.
The calculation of the mass of Mars was done well by the better candidates but many were unable equate the condition for circular motion to the gravitational force. Many of those who could only recall the expression for the gravitational acceleration in the field of a point mass equated it to the value at the surface given in part (d)(ii).

(d) This was often answered well by those who had failed to score on parts (b) and (c). The common errors were to write r for R in the formula or to forget the metre to kilometre conversion.

Q4 (a) Most candidates appreciated that the current was in opposite directions for the charge and discharge processes. However few made it clear that the current would have the same magnitude at the same instant in the process.

(b) Candidates were able to read the graph correctly and to appreciate that the scale was in milliamperes.

(c) In (i) a significant number confused time constant with half life and stated that 5 seconds was the time for the current to halve. Others were vague approximating the change to one third instead of stating 1/e or 0.37. Although pointed towards using the expression for the time constant many tried to use the capacitance formula and work backwards from part (d)(i) producing a circular argument. On the whole (ii) was done well.

(d) This section was completed well by almost all candidates. Some failed in part (iii) suggesting that the full formula for an exponential discharge should be used.

Q5 (a) Most candidates scored full marks for this part. The only common error was misreading 0.60 mm as 6.0 mm.

(b) Very few candidates were able to draw the correct magnetic field lines passing through the iron core and both coils. Many made no attempt and many drew solenoid patterns around the primary coil completely ignoring the presence of the iron core.
Most candidates appeared to be familiar with magnetic flux linkage so that at least one mark was scored in (ii). However few appreciated that a changing flux was necessary before a p.d. could be induced across the spark gap in (iii). However many were then able to continue by quoting Faraday's law and to explain that the p.d. would increase in (iv)1.
In part(iv)2 many candidates failed to distinguish between primary and secondary coils and wrote vaguely in terms of the ratio of turns increasing. The question was written with the primary coil stated before the secondary coil so the ratio, stated without further detail, should decrease to increase the p.d. across the spark gap.

Q6 (a) The differences between the nuclear radiations were often given in insufficient detail to gain both marks. For example it was not enough just to say that α-particles are positively charged and β-particles negatively charged; +2e and –e were needed to gain the second mark. Few candidates knew much about the differences between γ and X-radiation apart from their energy or wavelength.

(b) The explanations as to why the count rate rose to 640 s^{-1} were often too vague to score both marks in (i). More than half worked out that the new count rate was 1280 and more half of these calculated the final distance correctly

Q7 (a) Many candidates found this to be the question on which they scored their highest marks. Those who started by defining internal energy and then discussing the consequences of removing the potential energy term had the framework to score four out of the five marks without further thought. Others who ignored this approach found it quite difficult to gain more than two or three marks.

(b) In this part three were three quantities listed and three sections to the graph, making a minimum of nine possible comments each for one mark with a maximum of seven marks. Those who planned their answers managed to reach this total without difficulty. Some contradicted themselves for example by stating that kinetic energy increased with a corresponding decrease in potential energy; indicating that potential energy had been transformed into kinetic energy. Some considered that the potential energy decreased as the molecules moved further apart so that the potential energy in the gaseous state was less than that in the liquid state. Other common misconceptions were not uncommon in the variety of answers presented. One error which cause candidates to lose most marks was to think that the region AB was ice and CD water, i.e. that ice melts at 373 K. The quality of presentation and the standard of writing varied considerably, from excellent to very poor. There well many well structured answers to part (b) especially..

2825/01: Cosmology

General Comments
The entry for this paper was similar to that of recent years in both numbers and range of abilities. The great majority of candidates attempted all parts of the paper, suggesting that they had managed their time well. The standard of answers also matched that of recent years and demonstrated that many candidates had prepared well for the exam. Common areas where candidates lost credit included the manipulation of logarithmic equations, poorly structured descriptions in longer questions and simple errors of omission or powers of ten made in the course of a calculation.

Comments on Individual Questions

1.a.i The majority of candidates correctly understood that the heliocentric theory of the Universe placed the Sun in the centre. Answers stating that all planets orbited the Sun were accepted and this first mark was, unsurprisingly, gained by most candidates.

1.a.ii. The idea of retrograde motion proved more difficult to explain. Statements that a planet appears to move backwards gained no credit and some answers even implied that the direction of planetary motion was temporarily reversed. Credit was given for explanations where one planet overtakes another leading to apparent backwards movement when observed against a reference such as the stars in the night sky. Some candidates gained marks from diagrams, but as in previous examinations, these had to be labelled.

1.b.i This question was answered well. Most candidates knew the name and meaning of the *light year* but the *astronomical unit* was not so well understood by weaker candidates, the most common error being to use the diameter of the Earth's orbit.

1.b.ii The majority of answers to this part were correct but it was clear that, for many candidates, this question came down to one of comparing the *light year* with the *parsec*.

2.a. Most candidates knew Newton's law of gravitation and the most common reason for losing the mark was to write $g = GMm/ r^2$. An explanation of the symbols was required, where weak candidates showed some confusion between G and g, but it was sufficient give r as just the distance between masses, without introducing the concept of centre of mass.

2.b.i. The shape of the galaxy was well known, although the standard of drawing was variable. Marks were given for a central bulge with two side arms and on this occasion some leeway was given to the relative sizes. Answers showing two spiral arms from above, or a spherical galaxy, gained no credit.

2.b.ii. The answers to this part showed that a significant number of candidates are unclear about the position of the Sun in the galaxy. Many examples were seen which placed the Sun inside the central bulge or at the far end of an arm. The arrow indicating the direction of the resultant gravitational force on the Sun was expected to be shown pointing approximately towards the centre of mass. Thus, when the Sun was placed outside of the main arm the arrow should not have been parallel to the main axis of the galaxy. Candidates drawing a spiral diagram in 2.b.ii could nevertheless gain full marks on this question if the Sun was 2/3 from the centre and the arrow was drawn correctly.

2.c. This calculation was successfully attempted by a majority of the candidates, but power of ten errors were made by candidates of all abilities, through the use of kilometres. Most answers equated the gravitational force to the required centripetal force although many

examples of Kepler's 3rd law were seen. The latter method resulted in more errors, usually through the conversion of time units or neglecting to perform the final calculation correctly.
On the evidence of answers to this question alone, it would certainly be worthwhile for candidates to thoroughly check the stages of a calculation, especially when it can award 4 marks.

3.a. Many candidates could state that protons underwent fusion in the Sun's core, but fewer went on to explain that mass was converted to energy. Marks were lost through some careless errors. It was not unusual for the answer to refer to atoms, rather than nuclei and some used the term fission.
Credit was given to correct statements of the p-p equations, although these are not formally part of the syllabus.

3.b. This question showed that many candidates had a poor knowledge of the spectrum of visible light emitted by the Sun. It was rare for answers to include the emission of a continuous spectrum from the surface and few understood the role of absorption in the Sun's atmosphere which leads to Fraunhoffer lines.

3.c. Most candidates correctly stated that part D of the spectrum represented radio waves, but the other sections were less well known. Some answers showed the candidates thought UV waves to have a longer wavelength than IR waves.

3.d.i. The calculation was usually performed correctly. Some errors were evident in converting the time to seconds or in failing to do this conversion at all, using the time in years.

3.d.ii. Candidates found this part difficult. Most answers suggested the gravitational field or the density of the material in the Sun was responsible for reducing the speed of the photon. Candidates should be aware that photons are scattered by charged nuclei from their work on the early evolution of the Universe, but few were able to transfer this knowledge to the Sun's interior.

4.a. This question was well answered. The formation of red giants was usually explained clearly. Many candidates understood that the change in colour was due to a reduction in surface temperature but this would often be linked to a decrease in luminosity by those who failed to appreciate the role of the increase in surface area.

4.b.i. This question should have been straight forward but there were a good deal more errors than anticipated. Candidates either could not locate 6.5 days, read the absolute magnitude incorrectly or missed out the minus sign.

4.b.ii. The calculation of distance was generally performed well and candidates were not penalised a second time for an error made in b.i. However, apparent and absolute magnitude were sometimes confused and errors made when attempting to manipulate the logarithmic relationship.

4.b.iii. A good number of candidates realised that the important difference was that apparent magnitude took no account of distance whilst absolute magnitude placed all stars at 10 pc. Answers which did not address these central points tended to be vague and gained little credit.

5.a. Many candidates were well prepared for this question and took the opportunity to give a full account of the events which took place in the earliest moments of the Universe. Few candidates left this question unanswered and marks generally ranged from 2 to 5.
Credit was gained by referring to the expansion of the Universe or its accompanying temperature change, but few candidates used the term 'inflation' to describe this period.

Phrases such as ‘freezing out’ were accepted in relation to forces. With respect to the fundamental particles such as quarks, electrons and protons some reference to them being ‘formed’ or ‘made’ was expected: in an extended question such as this it is not sufficient to simply give a list of technical terms, without linking them together into a coherent answer.

5.b.i. The plotting of points generally caused few problems and candidates were given a tolerance half a square in each direction.

5.b.ii. The standard of graphs was variable. The curved line was not easy to draw completely correctly at one go and candidates who used a pencil, as is mentioned on the front page of the exam paper, may have had an advantage. There were some examples where candidates did not know how to deal with the peak and chose to draw a horizontal line between the two highest points. The frequency was usually read off from the graph correctly, but some candidates slipped up by giving the maximum relative intensity instead.

5.b.iii. This question gave a wider range of marks than expected. Common errors included using Ghz in the calculation, multiplying by 10^6 or 10^{12} which earned a penalty of one mark, or in using the equation $f = 1/\lambda$ which lost both marks.

5.b.iv. The calculation was performed well and any error in b.iii was carried forward without further penalty.

5.c. Most answers gained one mark by stating that the calculation provided evidence for the Big Bang theory, but there were fewer instances where candidates went on to describe the origin of the CMBR.

6.a. Many candidates knew the facts required for this question but failed to express them clearly. The term ‘red-shift’ frequently was not linked to the light received from a galaxy; ‘stars’ were referred to, when in fact ‘galaxies’ would have been more appropriate and weaker candidates would often not mention Hubble’s law at all.

6.b. The concepts of an open and closed Universe caused little difficulty. Many candidates thought that a flat Universe would stop expanding, often at its current size. Some answers reversed the density conditions for an open and closed Universe whilst some others made little progress by comparing the mass of the Universe with its critical density. Overall, a question which should have been reasonably straight forward, relying as it did upon recall of factual material, caused more problems than expected.

7.a.i. The concept of an inertial frame of reference within the special theory of relativity was well understood.

7.a.ii. This was answered well by many candidates. The most common omission was the role of an observer in a different inertial frame

.

7.b.i. The graph was generally sketched well. Most candidates began with the rest mass and continued with a near-horizontal line. It was clear that some candidates had difficulty deciding whether to draw an asymptote where the speed = *c* or simply to give the electron a finite mass at this point.

7.b.ii. This question was not answered well, overall. Very few candidates used the relativistic factor to explain how the mass changes. A similarly small number of answers showed an understanding that at low energies the work done by an accelerator goes to increasing the particle’s speed, whilst at high energies the majority of the work done increases the particle’s mass. Most candidates managed to gain some credit by stating that mass increases with speed, but then attempted to use the relation $E = mc^2$ as justification, leading them to conclude that mass is inversely proportional to the square of speed.

7.c. Notwithstanding the fact that this question was taken directly from the specification, there was a wide range of marks awarded.
The best answers usually began with a labelled diagram and outlined the ‘equipment’ and its arrangement. This would be followed by stating the measurements to be taken and the account could then be finished by quoting the principle of equivalence followed by a conclusion. Candidates using such a structure – equipment, measurements, conclusion – tended to score above average.
The range of experiments described was quite wide: many answers were not thought experiments at all, despite the word ‘thought’ being in bold type in the stem of the question.

2825/02 Health Physics

General Comments;
This examination produced a wide spread of marks. There were many good scripts. It was noticeable that a number of good candidates are still failing to achieve in the extended answer questions. It was common to find vague answers and with the MRI unstructured question, it was clear that many candidates did not understand the principles and wrote confused statements.

Comments on individual questions:

Q1(a) In general most candidates were able to describe correctly the shape of the graph. A common error was to misread the frequency axis scale so that the frequency range ended up as larger by a factor of 10^3.

(b)(i) This proved difficult for a number of candidates who offered a range of ways of substituting into the intensity level equation. A common error was to substitute 80 dB as the intensity in the equation.

(ii) Most candidates were able to suggest the subjective nature of loudness but many failed to give a definitive description of intensity.

(iii) Most candidates had a go but failed to give reasons that backed up their point of view.

Q2(a)(i) Very few candidates offered the wrong answer.

(ii) Most candidates were able to suggest that the power of the eye was too strong but explaining how the reshaping lowered the power proved difficult for many.
(b) Candidates were well prepared for this piece of extended writing. Most were able to get more than half of the available marks. There were still many responses which were ambiguous such as ‘the surgery is cleaner’.

Q3 The majority of responses showed confusion somewhere in the answer. MRI is a complicated topic which is studied briefly at a low level. Many candidates did not appreciate the significance of the rf radiation which is sent in. The order in which events occur is crucial to the gaining of marks. For example many discussed precession as the result of sending in rf radiation while others described switching on and off the magnetic field and measuring the relaxation times for the atoms to become *unaligned*. A number of candidates were so well prepared that they described and explained the reason for the magnetic field gradients across the length and width of the patient and went into the physics of the detection coils.

Q4 (a) The equation was well recalled with most gaining credit for reference to an attenuation constant.
(b)(i) The most common error was to calculate the log of the intensity, but this was usually changed when the scales did not fit the values.
(ii) The graph was well plotted with a few candidates failing to get the ‘line of best fit’ mark.
(iii) This was once again well done. A number of candidates omitted the negative sign indicating the direction of the gradient.
(iv) This proved difficult for many. A number started well with ‘22 = ln I_0’ but they were unable to continue on to the answer. Some took two values from the table together with the value for λ from (iii) and calculated a value.
(v) This again proved difficult for many. A number of candidates substituted values from the Table of Fig.4.1 into the equation in (a), calculated a value for λ and then finding a quarter of the value of I_0 in (b)(iv) used the whole page to end up with an answer. Those who took the logical route finished this in two lines.

Q5. (a)(i) Most candidates were able to state the equation. A few did not explain the meaning of the symbols used.
(ii) The most common error was to put the unit of absorbed dose as Sv rather than Gy. A few candidates omitted the factor of 10^{-3}. Most were able to gain full credit.
(iii) If the answer to (ii) was correct, then it was usual to see that this part was also correct. The most common error was '$3 \times 10^{-3} \times 1.6$'.
(b)(i) It was pleasing to see that most candidates had learned this topic and were able to score here. There were a number who mixed macroscopic and microscopic terms, such as 'the tissues are ionised'.
(ii) There was some confusion as to the meaning of the term *stochastic*. It was clear that many had been taught this but the ability to express their knowledge let them down. For example a significant number of candidates in trying to say 'there is no threshold dose' said that 'above a minimum dose, the greater the exposure, the more severe the damage'.

Q6.(a) About 2/3 of the candidates were able to do this. The terms *first* and *second class lever systems* are not specification terms, however most candidates were able to use their physics knowledge to answer the questions which contained these terms.
(b)(i)(ii)(iii) It was common to find that either cos 60 or sin 30 was used here. The other common mistake was to use N m for the unit where the cm lengths given in the question had not been converted into m.
(iv) Much discussion was made without reference to either the anti-clockwise moment or the distance of the line of action of the load to the pivot. Merely saying that 'the angle gets bigger so the effort must increase to compensate' is not enough for the full three marks.

Q7.(a)(i) The most common error was to think that surface area of a sphere was $4/3\ \pi\ r^2$.
(ii) Very few candidates were able to score here. Many started with $E = mc^2$.
(b) A few candidates failed to make reference to the atmosphere and so lost the marks while others used the term 'lost' to say where the energy went.
(c)(i)(ii)(iii) These three parts of the question were accessible to all candidates. A few expressed the efficiency as a fraction (which was given credit).
(iv) This part of the paper was often full of numbers with little structure. It differentiated well although the question required a logical sequence of tasks and little knowledge.
(d)(i) ¾ of candidates were able to get to the correct answer. A minority calculated the temperature difference and then added 273 to their answer.
(ii) While most got the idea that the time would be longer, less than half were able to get the second mark.

2825/03 Materials

General Comment
Centres are now very familiar with the specification for this option and the type of question which is set. It is clear from the responses of most candidates that the subject matter is well taught and that candidates are well prepared for the examination. Consequently for the most able candidates, definitions are well rehearsed, most of the calculations are routine, and descriptions and explanations are soundly expressed. However, in the middle and lower sections of the performance range, the subtler points in some questions and the requirement for a step-by-step approach to an explanation proved more of an obstacle and their final mark suffered accordingly.
The marks gained by candidates were well distributed over the questions, all of which included sections which enabled candidates across the full range of grades to show their ability.
A grade candidates gained all but a few of the marks on each question; B and C grade candidates tended to score more than half marks on each question. Other candidates found parts in each question which they could successfully cope with, leaving very few blank spaces on the paper. The number of candidates who 'gave up' on the paper was extremely small, so marks below 20 out of the 90 available were rare.
Overall, the quality of answers seen on the scripts was indicative that much serious and intense work had been done.

Question 1
Q 1. (a) Surprisingly few candidates knew that a diamond gem-stone is a single crystal, but most could identify metallic glass as amorphous.
(b) A large majority gained both marks.
(c) (i) Most candidates were successful in naming a dislocation or (more rarely) a line defect.
(ii) Sketches showing various subsequent arrangements of the atoms were drawn, most showing careful attention to detail and worth the 2 marks.
(iii) Answers referring to the force required to break bonds were required, rather than the ease with which planes of atoms slipped. Few answers were successful.
(d) Many different examples of metal objects were quoted. As long as the desired shape could be acquired by hammering, shaping, pressing, stretching or extrusion, the suggestions were accepted.

Question 2
Q 2.(a) In (i) many answers were let down by ignorance of the correct formula for the surface area of a sphere. Fortunately for many, the 'show that' feature of (i) allowed a successful calculation in (ii).
(b) (i) Several circuits were drawn without a power supply.
(ii) 10 marking points were available; 8 were needed. Most candidates gained 5 or 6.
A majority of answers failed to address the need to calculate the power falling on the face of the LDR, in spite of the hint given in part (a) of the question. Only a few candidates dealt with the choice of current meter. Many failed to mention the need to exclude light from other sources than the bulb.
(iii) A common omission was the point that a more intense light source emits more photons per unit time.

Question 3
Q 3.(a) Many candidates failed to place the + and – signs correctly on the figure, but gained 1 or 2 of the subsequent marks.
(b) Most were completely successful with the calculation. In (ii) a minority misquoted the formula or failed to transpose it correctly.

(c) A logical sequence starting with the reduction of charge carriers in the conduction band compared with a metal was required. Candidates who took this approach tended to score 3 or 4 marks. Many had entirely the wrong idea.

Question 4
Q 4.(a) A very large majority of candidates could give appropriate explanations, expressing correct ideas about dipoles.
(b) Candidates were expected to address the issues of energy loss due to eddy currents and hysteresis, the requirement for a high flux density in a small core, and the need to nullify the effect of very high temperature. Most made good attempts at the energyloss measures. Surprisingly few, in spite of the hint contained in (a), wrote about the need for a high Curie temperature or a high melting point. Some made fairly vague references to flux. Of the 10 possible marking points, of which 8 were required, the best candidates gained 6 or 7, reducing to 3 or 4 for the weaker answers.

Question 5
Q 5 .(a) (i) This basic calculation caused few problems. Several candidates however, quoted frequency as the reciprocal of wavelength.
(ii) The conversion of energy from joules to electron-volts proved a stumbling block for a large proportion of candidates.
(b) Candidates who failed to mention photons lost a mark. Most candidates could deal adequately with the behaviour of the sheet of glass. In the case of metal, they needed to refer to close energy levels in the conduction band, or overlapping conduction and valence bands. Those who wrote about an energy gap in the metal also lost a mark.
(c) Lower frequency or increased wavelength for the emerging gamma photons gained the mark, as did the suggestion that X-rays emerged. Reduction in speed clearly did not.

Question 6
Q 6.(a) (i) Most candidates could state two of the possible ways that light could be absorbed, but some wrongly quoted Rayleigh scattering at this stage.
(ii) Those who had successfully answered (i) almost invariably and correctly gave Rayleigh scattering here.
(b) Only a few suggested an increase in speed.
(c) (i) An emerging pulse of longer duration and with a bell-shaped top was required. A minority drew a pulse of the same duration.
(ii) Most candidates dealt satisfactorily with multipath dispersion. Many fewer also wrote about material dispersion.

Question 7
Q 7.(Question common to all 5 options)
The strongest candidates gained in excess of 15 of the 20 possible marks. Most of the weaker candidates approached half marks.
(a) (i) In **1** many candidates lost a mark through not knowing the surface area formula, but most of these gained the mark in **2**.
(ii) A large proportion did not appreciate that this calculation required the mass-energy conversion expression.
(b) (i) Absorption or reflection in the atmosphere or ionosphere was expected. Mention of the atmosphere or ionosphere alone was not rewarded. Neither was the suggestion of reflection from the Earth’s surface.
(ii) A greater thickness of atmosphere or the spread of the radiation over a greater surface area were required. Greater distance from the Sun was not rewarded.
(c) (i) (ii) and (iii) involved well known physics and gained the 4 marks.
(iv) Completely correct answers were frequent, but the several stages in the calculation provided pitfalls for many.
(d) (i) Full marks was the common outcome.

(ii) Many candidates clearly missed the point that maximum solar power was to be assumed, and therefore made invalid suggestions. A suggestion that heating with a panel took too long was accepted, but few achieved the second mark.

2825/04 Nuclear and Particle Physics

General Comments

As usual there was a wide spread of marks between the very able, well prepared candidates and those who failed to attempt large parts of the paper, but in general candidates responded well to the paper and seemed to be able to demonstrate what they knew and could do.

This year the tendency to refer to 'atoms' or even 'molecules' was noticeably more in evidence, when the candidate should have been referring to nuclei.

There were also several questions in this year's paper (eg 4(a)(i),(ii)) where, in order to facilitate the candidate's progress through the question, an approximate value for an answer was given. The purpose of this is to enable the candidate to tackle the later parts of a question, even though s/he has failed to arrive at an answer to an earlier part. However, the examiner still needs to see the candidate's own answer so that credit can be awarded for carrying out the calculation. Where this was done candidates often stated a great many significant figures (8 or 9 in some cases) and were not penalised for so doing, though normally 3 significant figures are satisfactory. However, shortening a value to 2, or even 1 significant figure during the calculation was sometimes penalised. However it would help both the candidate and the examiner if *standard form* were used.

An error which occurred more widely in this examination than previously was confusion between 1.6×10^{-19} C (the elementary charge), 1.66×10^{-27} kg (the atomic mass constant) and 1.67×10^{-27} kg (the mass of the proton) and a number of candidates lost credit accordingly.

Some candidates need to take more care when representing neutrinos and gamma photons – these symbols were indistinguishable on some scripts.

It has been referred to in previous reports but it still needs stressing that the answer to a question which begins with 'Show that…' needs to show all the steps in the working to gain full credit. Answers to questions beginning 'Calculate…' should also show working, but full credit can be gained with a less full answer, providing the correct numerical result is arrived at.

A few weaker candidates were unable to finish but the great majority continued to score right up to the end of the paper.

Comments on Individual Questions

1(a)(i) Nearly all candidates were able to calculate the mass of an aluminium nucleus by multiplying the given mass of a nucleon by 27. Very few problems were experienced.

(ii) It was also pleasing to see that the great majority of candidates were able to use the given equation to form an expression for the radius of the aluminium nucleus, to substitute into the correctly recalled formula for the volume of a sphere and to arrive at a correct value.

(iii) This part merely required candidates to apply successfully the density formula and nearly all were able to do this, though some failed to write down the answer to their own calculation, being content to give the approximate value quoted in the question.

(b) This part was intended to test whether candidates realised that the density of all nuclei is the same and their understanding that this is true because the nucleons in all nuclei are equally spaced. Many were able to state that the density of the gold nucleus is the same as that already calculated for the aluminium nucleus. This could be done by a statement or simply by writing down the same density as they calculated in *(a)(iii)*. Candidates were less successful in explaining, *in terms of nuclear structure*, why this should be so. Many answers were framed in terms of the mathematics of calculating the density value and as such made no reference to the Physics of the situation. Credit was however given for the statement that the volume of the nucleus is proportional to the number of nucleons and so this factor will cancel out. However, no credit was awarded to those who referred to the fact that most of the atom is empty space. This was also popular in *(c)(ii)* to explain what could be deduced from the given relationship. Many candidates thought that since the gold nucleus contains about 7 times as many nucleons, that it must be 7 times as dense as the aluminium nucleus.

(c)(i) In this part candidates were expected to calculate the ratio of both the atomic masses and the densities of gold and aluminium metals and thereby show that the values were approximately equal. It had been anticipated that this would be an easy, low-level mark; the

responses in many cases proved otherwise. A surprisingly large number of candidates wrote down the two fractions but failed to evaluate either of them, perhaps expecting that the seeming similarity of the expressions would be enough to establish their identity. Even fewer were able to state correctly that it was necessary to assume that the mass of an atom is the same as the mass of the corresponding nucleus, i.e. that the mass of the electrons is negligible. Weaker candidates either did not know what to do or did not know how to calculate the mass of the gold nucleus. Some simply stated the obvious, namely that the density of the metal seems to be proportional to the mass of its atoms.

(ii) Candidates were expected to deduce that since the ratio of the densities of gold and aluminium is equal to the ratio of the masses of gold atoms to aluminium atoms, the two atoms must occupy the same amount of space as each other. This was a question in which clarity as to the difference between 'nucleus' and 'atom' was essential and some candidates failed to display this. Many candidates failed to score in this part, some simply stating that density is proportional to mass.

2(a) Candidates were expected to state that in nuclear fission a nucleus, triggered by in incoming neutron, splits into two smaller nuclei, whereas, in radioactive nuclear decay a nucleus can spontaneously emit an alpha or beta particle or gamma photon. This was generally well answered though a surprisingly large proportion of candidates were hazy about radioactive decay, stating that it occurred 'randomly' or 'naturally' without making it clear that these reactions are spontaneous unlike fission, or making vague statements about 'particles' being emitted without making it clear they were referring to alpha or beta particles or gamma photons. Occasionally candidates lost credit by referring to atoms rather than nuclei. However, there were enough marking points for most candidates to score.

(b)(i) In order to explain why the mass yield *versus* nucleon number graph is symmetrical, candidates were expected to state that the nucleon numbers of the two fission products must add up to the nucleon number of the parent nucleus, and that therefore for every small product nucleus there must be another, large nucleus. This was generally well understood though many candidates who seemed to have grasped it nevertheless were unable adequately to explain it to the examiner. A few incorrectly referred to 'atomic number', a term not normally needed in this option which really refers to the proton number. Others tried unsuccessfully to explain the position of the peaks or why the yield should be the same for the two nuclei emitted.

(ii) Candidates were asked to state the proton number and nucleon number of the nuclei produced by a 50-50 split. This was achieved by most candidates though a surprisingly large number failed to score. The reasons for this included failure to include the mass of the incoming neutron which triggered the reaction and so giving the nucleon number as 235/2 = 117.5 instead of 236/2 = 118. This was probably also the error which prompted answers of 117. A few entered the proton and nucleon numbers in reverse order. Others gave the proton and neutron numbers.

(c) In this part candidates were asked to deduce the proton and neutron numbers of a particular fission product, assuming that two neutrons were emitted. Although a little harder than *(b)(ii)*, this was equally well done, carelessness being the main cause of error.

(d) Most candidates were able to write equations which scored some credit. The main omission was the neutrino in the beta emission. A few showed the residual nucleus of the beta emission as iodine-140 rather than xenon-140. Others did not represent the emitted beta particle correctly.

(ii) Candidates were expected to point out that the iodine-140 is likely to be neutron-rich and that, apart from emission of a neutron, it can reduce the neutron/proton ratio by the conversion of a neutron to a proton with the emission of a beta-minus particle. This part was less well done. Weaker candidates, presumably lacking a valid reason, vaguely referred to lack of stability of the iodine-140 or the supposed greater stability of the product(s) of decay. 'Binding energy' and 'mass loss' were alluded to by some.

(iii) This was a fairly routine calculation of a type which has featured in many previous papers. Candidates were required to find the mass defect for each of the suggested reactions and then to state that only the one which resulted in a *loss* of rest mass could actually occur. Many candidates were able to score full credit though a significant minority lost marks either by arithmetic errors in their calculation of the mass defect or because they drew the wrong conclusion from a mass gain or loss. Some candidates lost all credit for this calculation because

they multiplied each nuclear mass by the mass number. Some stated that the reactions could not take place due to the mass not being conserved.

3(a)(i) Nearly all candidates were able to substitute values for the proton charge , permittivity and given charge separation in order to calculate the potential energy of two charges. The few who failed usually doubled the proton charge instead of squaring it, or substituted the elementary charge as 1.

(ii) There was less success in stating the relationship between the potential energy and the kinetic energy of *each* nucleus. Since there were two hydrogen nuclei sharing the energy, the kinetic energy of each nucleus is only half of the total potential energy. Many candidates omitted this factor 2, stating that the two energies are equal. Others stated that they were proportional or even inversely proportional to each other. Others again suggested that the sum of potential energy and kinetic energy is equal to 2.0×10^{-15} J.

(iii) In this part candidates were asked to use the given formula to find the temperature inside the Sun at which the kinetic energy of protons is equal to the value implied by the equation in *(ii)* and to show that this temperature is greater than 2.5×10^{9} K. For those who had correctly related the kinetic energy and potential energy in *(ii)* this was a straightforward answer which quickly earned 2 marks. Those who had equated (incorrectly) the energies in *(ii)* but who followed through consistently were also able to score fully. However a significant number of candidates, having omitted the factor of 2 in *(ii)* then reintroduced it without explanation in *(iii)* and scored a maximum of only 1 of the 2 marks. Others began their answer to *(iii)* by stating correctly that $E_K = {}^3/_2\, kT$. This is, in effect the equation given and could have resulted in a correct answer; however these candidates usually got lost and failed to score. In this part, as in others, the use of standard form for expressing an answer would have been more satisfactory.

(iv) Here candidates were asked to explain why hydrogen nuclei do fuse inside the Sun, even though its temperature is well below 2.5×10^{9} K. It was expected that candidates would realise that the kinetic energies of hydrogen nuclei in the Sun cover a wide range of values and that the value given is only a mean. There are therefore some nuclei which, at any given moment, are well above the mean value and so these nuclei are able to fuse. Better candidates were able to state this and score full credit. However, many attributed the phenomenon to the high pressure or the strong gravitational field inside the Sun, forgetting that pressure is a macroscopic quantity and therefore not relevant to a discussion of fusion between individual nuclei. Others made statements such as '..some nuclei are at a higher temperature and so they can fuse..'. Again there was confusion between a nuclear phenomenon (nuclear fusion) and a macroscopic effect (temperature). Others again stated that the large number of hydrogen nuclei inside the Sun is responsible, a factor relevant only if some of them have the required amount of kinetic energy. However a significant minority of candidates were aware that the phenomenon of quantum tunnelling could allow fusion to take place at separations greater than the expected one and this answer was rewarded.

(b) Most candidates were able to explain that since the hydrogen nucleus is a single nucleon there is no binding or splitting and therefore no binding energy is involved. Few failed to score.

(c(i)) Many candidates were able to state the standard equation for the fusion of four hydrogen nuclei though some omitted the neutrinos.

(ii) This was a straightforward calculation of a type which is specified in the syllabus, has been set many times before and which many candidates succeeded in completing. As usual where credit was lost it was because candidates forgot that the graph showed binding energy *per nucleon* and so failed to multiply by four (nucleons in the helium nucleus). A few incurred a power of ten penalty because they omitted the factor of 10^6 in converting MeV to eV. A significant minority of candidates tried to use the equation $E = mc^2$; however, since only a small part of the rest mass is converted to energy, this method greatly overestimates the energy released.

*4(a)(i)*Most candidates were able to apply the usual equation for the rotation of a charged particle in a circle and to use the value given for the radius of the dees of the cyclotron to find the maximum speed of the protons. However, since they were asked to 'Show that…' it was expected that they would write every step in their answer, including the initial equation. As indicated earlier, they were expected to state their derived answer and not merely the approximate value stated in the question.

(ii) Most were then able to derive a value for the kinetic energy of the proton in joule and then convert it to MeV. Again it was expected that they would give their own derived value and not merely copy the estimated answer given.

(b) There were several slightly different but equivalent methods of finding the frequency of the source of potential difference. In effect all methods involved finding the time taken by a proton to complete one revolution and then stating that the frequency is the reciprocal of time period. Many candidates succeeded in this, sometimes using an algebraic method to derive a formula for the period or frequency before substituting values. A few arrived at double the correct answer either by taking the circumference of a circle to be πR or by assuming that the alternating potential difference passes through *two* cycles during each revolution of the proton.

(c) This part required candidates to realise that each time a proton completes a half cycle, it gains 80.0 keV of energy so that in order to find the number of revolutions it was necessary to divide 2x80 keV into the total energy gained i.e. 17.3 MeV. Many failed to achieve this, probably because they assumed that they could deduce the number of revolutions from their answer to *(b).* Others lost some credit by assuming that the proton gains 80 keV only after completing a whole revolution. These candidates arrived at an answer indicating that twice as many revolutions would be needed.

(d)(i) Candidates were expected to know that the magnetic field in a cyclotron must be uniform in order that the time for a revolution would remain constant, no matter what the radius of the orbit and to justify this by reference to the factors affecting the time period. Since this period depends on the mass of the proton and its charge, both of which are constant, the only factor which could cause the period to change is the strength of the magnetic field. This part was poorly answered; answers such as '..the magnetic field must stay constant to keep the centripetal force constant..' or '..to keep the proton moving in a circle..' were common but insufficient.

(ii) Here candidates were asked state how the field needs to be non-uniform in order to compensate for the gain in mass of a proton as its speed approaches the speed of light. Many candidates were aware that a more massive proton would need a stronger field but most failed to point out that this could be done only by making the field stronger near the outer edge. Increasing the strength of the field in *time* is not possible because at any given moment protons with many different speeds and masses will be in motion. This part also was answered poorly by most candidates.

(5) In this question candidates were asked to give an extended account of the three forces which act between nucleons in the nucleus. The question was generally well done by candidates stating which forces are long and which short range, by giving detail about how each varies with separation, by stating which kind of force acts on which particle and by stating the relative importance of each. Answers did however reveal some misunderstandings about, for example, the meaning of 'long range' and 'short range' forces. Some candidates thought that a long range force is one whose size *increases* with distance apart. Others classified the electrostatic (or electromagnetic) force as a short range force. Many lost credit through careless drawing of force-separation graphs. Errors which occurred most often were to make the strong force graph asymptotic to the separation axis making it appear to be a long range force, whereas in fact the strong force falls to zero at a small separation. Sketch graphs of the electrostatic force often lost credit because it was not clear that this graph *is* asymptotic at both axes. Some candidates wasted time, having already given a sketch graph for the strong force, by then describing the variation verbally. Others, having drawn a potentially correct graph, failed to state what force it referred to and so failed to score credit for it. The gravitational force plays no significant part in the structure of the nucleus, so detailed description of it scored less credit than for the strong and electrostatic forces. This piece of continuous writing requires more care with choice of words and clarity of handwriting; credit was lost in some cases by misplaced references to 'neutron', nucleus' and 'nucleon', or vaguely, to 'particles'. More fundamentally, a few candidates discussed the weak force. This is considered to be another aspect of the electromagnetic force and plays a part in beta emission but is not a force acting between nucleons, as required by the question. A number of candidates stated that the electrostatic and/or gravitational force varied 'exponentially' with separation but seemed to see no contradiction in subsequently stating that the force varied with separation in an inverse square manner. There were many statements to

the effect that the strong force is 'greater' or 'more important' than the electrostatic force, though these two forces were often subsequently stated to be in equilibrium in the nucleus.

6(a) Nearly all candidates were able to state that the neutron and proton are hadrons or baryons.

(b)(i) Equally, practically all candidates knew that the proton is stable when it is part of a nucleus.

(ii) Many candidates stated the estimated lifetime of a free proton as 10^{32} years but omitted to make any statement about its stability. Of those who did, some described it as 'unstable' or only 'fairly stable', despite no proton decay ever occurring, or being likely to.

(c) This was a question about radioactive decay, of a type which has been set before both on this paper and 2824, and many candidates successfully solved it by using the decay equation. Where marks were lost it was usually either because the answer given was the number of neutrons which *did* decay or because the candidate used the activity equation to find the rate of decay and (assuming the rate of decay is constant) calculated the number remaining after 200 seconds. Some weaker candidates, however, were at a loss to know where to begin.

(d)(i) Most candidates were able to state the charge and baryon number of the down quark and the neutron.

(ii) Likewise most were able to give numerical equations to show how the charge and baryon numbers of the quarks add up to the corresponding values for the neutron.

7 This question on general Physics was generally well answered and provided a good opportunity for candidates to display their grasp and knowledge of core topics.

(a)(i)1 Many candidates were able to recall the formula for the surface area of a sphere and to substitute the radius of the Earth's orbit in order to find the surface area of the specified notional sphere. Those who failed to score usually did not know, or wrongly remembered, the expression for the surface area of a sphere.

2 Many successfully multiplied the area calculated in *1* by the given intensity to confirm the total power output of the Sun.

(ii) Use of the equation $E = mc^2$ enabled good candidates to calculate the rate of conversion of mass to energy inside the Sun. Weaker candidates usually failed to score, possibly unable to cope with the idea of a *rate* of conversion of energy.

(b)(i) Most realised that the reason that the intensity at the surface of the Earth is less than the intensity incident on the upper atmosphere is that energy is reflected, scattered or absorbed by the atmosphere itself. Stating that the energy (or the 'light') is 'lost' in the atmosphere was not sufficient.

(ii) This part was less well done; candidates were expected to realise that to reach places on the Earth far from the equator the energy has to pass through a greater depth of atmosphere which therefore absorbs a higher proportion of it. Many lost credit here by regarding this reduction in intensity as due to the inverse square law of radiation. Although the distance travelled by the radiation in reaching the Earth's surface is slightly greater for these places on the Earth, the extra distance is so small in relation to the Earth-Sun distance that the effect is entirely trivial.

(c)(i) Nearly all candidates were able to calculate the solar input as the product of the solar intensity and the area of the solar panel. A small number *divided* by the area.

(ii) Most correctly calculated the product of the current and potential difference delivered by the solar panel to find the power generated.

(iii) Division of the answer to *(ii)* by the answer to *(i)* enabled most candidates to find the efficiency of the panel. A small number of candidates lost credit by confusing percentage with proportion, usually adding a % sign when no factor of 100 had been used.

(iv) Calculating the height of the fountain of water essentially involved equating the energy input per second to the gain of gravitational potential energy of the water. Where errors did occur they usually involved either incorrect application of the efficiency, failure to calculate the mass of water given its volume, or omission of the factor of 3600 to convert from a mass per hour to a mass per second. Some did however arrive at a correct value for the height. Weaker candidates often failed to score.

(d)(i) This was a straightforward application of the equation $E = mc\theta$ to find an expression for the energy needed to raise the temperature of the water through 75^{o}C and then to divide by the

power of the solar panel to find how long the water takes to boil. Most candidates were able to do this. A few lost credit by inappropriate use of Kelvin temperature.

(ii) Most candidates were able to suggest one reason why the proposed solar heater would be unsatisfactory. Usually candidates referred to the long time it would take. Some stated that a very large solar panel would be needed or that the heat losses over such a long heating period would be unacceptably high. Many referred to costs of this method but simply stating that '..it would cost too much..' was insufficient to score. Many sensibly compared the proposed heater with the mains though few pointed out that not only is the heating time much longer than for this kettle; the mass of water being boiled is also much less than would normally be used. Many also stated that solar heating would be unsatisfactory because the Sun does not shine all the time, even though the question had specified that we were considering only the case when the solar power is a maximum.

2825 / 05A2 Physics Option Telecommunications

General Comment

This summer, fewer than ninety candidates opted to take the Telecommunications module representing under two percent of the total possible. However, this small and determined group arrived very well prepared for the examination and revealed a high level of knowledge and competence in their chosen topic. Mistakes were often careless rather than fundamental and the examiner repeatedly awarded marks after allowing an error carried forward (ECF) in all questions. Indeed, there were no worthless scripts and clearly almost everyone had made a commendable effort to learn the material as thoroughly as possible.

Question 1

(a) Almost all candidates correctly answered Amplitude Modulation for the given signal. Although all candidates knew the frequency to be the reciprocal of the period there were many errors made in deciding the periods of the transmission and modulating signals. Quite a few got them mixed up. The carrier or transmission frequency is 400 kHz and the modulating frequency is 40 kHz. This places the carrier in the Medium Frequency waveband (although the mark could be scored through ECF). Future candidates should note that an answer of MF was not acceptable and received no mark.

(b) Only about half candidates correctly answered that the reason the radio could not play the information was because the modulating signal frequency of 40 kHz was way beyond the tuning bandwidth of an AM receiver and anyway was way beyond human hearing and also beyond the ability of a loudspeaker to reproduce it.

(c) Most candidates correctly drew three vertical lines for the frequency spectrum as required and quite a lot of ECF was allowed in their marked frequencies.
Almost all candidates correctly defined the bandwidth as the range of frequencies present and gained a mark for writing down the bandwidth from their frequency spectrum.

Question 2

(a) Almost all candidates knew the meaning of LDR as a Light Dependent Resistor. A significant minority incorrectly answered that when a torch is switched on the resistance would increase (which involved the examiner in ECF in part (c)).

(b) Surprisingly, around half of the candidates made the same error in calculating the current in the LDR by simply dividing the 9V by the 230 Ω (carelessly forgetting to add the 270Ω in series). This often ruined their calculation of the voltage at A and B. However, most correctly realised that as A and B are equal, the op-amp output would be zero and the motor would not turn.

(c) A large number of candidates correctly explained that when torch X is switched off the voltage at A will fall relative to B's constant value so the op amp will saturate positively and the motor will turn.

(d) These candidates then went on to state correctly that when both torches are off the motor will not turn because again the op-amp output is zero. When torch X is on and Y off the motor should turn the other way. Quite a few candidates clearly did not understand the behaviour of a simple d.c. motor. They thought the motor could only turn in one direction i.e. during the positive saturation of the op-amp and would not turn on when the op-amp output was negative.

(e) Most candidates made a decent attempt at suggesting why the intended behaviour of the motor would not be realised in practice. The essential point is that with such a high open-loop gain the op-amp is likely to spend its life saturated in one direction or another with the motor running at full speed in one direction or another. There were quite a few woolly answers to why negative feedback would improve the circuit performance but most candidates were awarded at least one mark for their efforts.

Question 3

(a) Although most candidates knew the formula $R = \rho l/A$ there was often a great deal of fudge in evidence as they tried to show the resistance of the copper wires to be about 11Ω. Quite a few used 125 m in the calculation and then realised their error so doubled their answer. Many did not appreciate that 0.40 mm^2 meant 4×10^{-7} m^2 and a few avoided this problem by working in mm rather than m (although that threw up problems of its own). Similarly, many made it difficult for themselves in their calculation of the voltmeter reading V_2 being about 7V by considering the copper wires and load resistor to be in parallel.

(b) While the majority of candidates knew the appropriate formulae for power in electrical circuits, there were lots of errors made due to an incorrectly calculated current in the circuit. Consequently, there was a lot of ECF allowed in the calculation of the attenuation in the cable which was generally very well answered. A large number of candidates, however, spoiled their final answer by taking the length of the cable to be 0.250 km instead of 0.125 km.

Question 4

While most candidates seemed reasonably well versed in the names of the elements of a simple radio receiver many were penalised for poor explanations of their function. For example; while a mark was awarded for correctly stating that block 3 is a Radio Frequency amplifier no mark was awarded for an explanation which said that this block amplified radio frequencies. To gain the available mark, the candidate was expected to answer that the RF amplifier was necessary to boost the radio signal to allow the demodulator to work.

Question 5

(a) Almost all candidates knew that multiplexing was the process of allowing several users to share the same channel although quite a few failed to state that it is important in the reduction of the cost of using the channel.
While most candidates seemed to know the very basics of FDM and TDM their explanations often left important differences unstated. The essential points are that in FDM the user is allocated a fixed region of frequency space in which they can transmit at any time while in TDM the user is allocated a series of time slots in which they can transmit any frequency.

(b) While most candidates stated the maximum frequency of analogue signal which can be digitised to be 250 Hz they did not always give a satisfactory explanation for it. They should have pointed out that the sampling frequency must be greater than twice the maximum signal frequency.
Although quite a few candidates correctly calculated the duration of each sample to be 4 x 2.5 = 10 μs they failed to use this correctly to show that the maximum number of digitised signals in the optic fibre is 200.
Although it was clearly labelled in Fig.5.1 where the light first emerges from the optic fibre, a large number of candidates worked from the other end and thus ended up with the reverse order of samples for graphs A and B. Using TDM, signal A is a falling ramp in voltage while that of B is a square wave (although any oscillating shape encompassing the correct binary conversions was allowed).
Quite a large number of candidates were able to show correctly that the frequency of signal B was 125 Hz.

Question 6

(a) A large proportion of candidates did not know the formula $4\pi r^2$ for the surface area of a sphere and thus were unable to answer part 1. Significantly more, however, did know that the product of the intensity and surface area gave the answer to part 2.
Only a minority of candidates realised the Sun's total power had to be divided by the speed of light squared in order to calculate the rate of conversion of mass to energy.

(b) Most candidates correctly realised the reason the sun's lower intensity at the surface of the Earth is due to atmospheric absorption and that intensity decreases with distance from the equator due to an increasing atmospheric distance.

(c) Almost all candidates were awarded some marks for their calculations towards showing a 60W power input, a 4.6W power output and a 7.7% efficiency (lots of ECF here). However, a significantly lower number were able to use the pump power of 4.6W with 35% efficiency to show that the mass of water raised per second would be 500 / 3600 = 0.14 kg s^{-1} and thus the maximum height reached would be 1.18 m.

(d) Most candidates correctly showed the time taken for the solar panel to boil the water would be 1970 seconds.

Almost all candidates scored at least one of the two available marks for any sensible reason why solar powered kettles will not be replacing mains powered ones any time soon.

2826/01 Unifying Concepts in Physics

General Comments
Many of the comments made in last year's report on this paper still hold. Candidates are still reluctant to use words rather than symbols and many still do not do enough practice during their course. A significant number of candidates treat physics questions as finding a formula and putting in some numbers. Whatever the question, and however many steps are required to evaluate the answer, many candidates start by writing down a symbol for the quantity being evaluated, hoping that a formula for the answer can be remembered. When preliminary steps are required these need to be done first. At this stage sketches are useful for the candidate. This was particularly so this year with some of the units. Probably only 30 – 40% of the entry could correctly change 50 km^2 into m^2. Answers of 50 000 m^2 and 2.5 x 10^9 m^2 were far more popular than 5 x 10^7 m^2. Many just used 50. A simple sketch of a square with one side labelled 1 km and one labelled 1000 m will immediately establish that 1 km^2 is 1 000 000 m^2, reliably giving the answer required for 50 km^2. This was seldom done. Thoughtful work is immediately apparent to markers and gains high marks; sloppy answers are often full of unnecessary mistakes resulting in poor marks. Poor handwriting handicaps a minority of candidates. Virtually all the candidates completed the paper in the allotted time.

Comments on Individual Questions

Question 1
1. This question produced marks covering the whole range from 1 to 14. A few candidates even managed to get (a) (i) wrong. In answering (a)(ii), many thought that by the time a firework rocket had reached the top of its travel it was so far away from the Earth that the gravitational force acting on it was much reduced. These people no doubt think that one way of losing weight is to measure your weight at the top of a nearby hill. The considerable air resistance on the rocket, together with its weight give the rocket a large downward acceleration after all the rocket fuel has been burnt and while the rocket is still rising. Far too many have no concept of a downward acceleration while rising. In answering (b)(i) weak candidates often marked P at the point of largest upward velocity, rather than at the point where upward velocity changes to downward velocity. Answers of 38 x 1.4 and ½ x 38 x 1.4 were too common for (b)(ii). These candidates often mentioned the area under the graph but their answers were considerably different from the values accepted in the range 16 – 22 m s^{-1}. Part (c) was answered quite well. An upward curve in the first section, a continued increase in the second and a downward straight line to zero in the last section were the points being looked for.

Question 2
2. The ideas being tested in this question were generally known, but many answers were poor nevertheless. In part (a), for example, too many candidates simply said that it was because there is no potential energy. Many went as far as to say that there is no <u>gravitational</u> potential energy. Too few candidates related the lack of potential energy of molecules in an ideal gas with the absence of force acting between the molecules. Part (b)(i) was done well and a wide range of actual values was accepted provided the working was done correctly. Many candidates lost marks by taking one small square as 1%. Part (b)(ii) was not answered well. The effect wanted here was something such as evaporation or chemical reaction. Part (c) was not done well and did not discriminate. It was not expected that candidates would have seen these graphs previously but would have been able to construct them in the exam. In part they did. A and B were done reasonably well but not enough attention was paid to the fact that there would still be 100% of molecules. The effect is to get the same area beneath the graphs and to do this A will be wider and lower and B will be narrower and higher. C will remain the same is there is no change in temperature and so will D, because of the use of percentage.

Question 3

3. This proved to be the easiest question on the paper, with many candidates scoring full marks. It was interesting to see a little note on one good candidate's paper. Having found the mass of water correctly to be 2000 kg he added, in brackets, "this seems an awful lot". Many weak candidates could see nothing wrong with a huge tank of water containing only 2 kg of water – even after seeing in the next question that the density of sea water is 1030 kg m^{-3}. Most could correct (b) and (c) though one candidate thought that the *V* in the $pV = nRT$ equation ought to be the velocity of the gas molecules.

Question 4

4. This was the question where careless mistakes abounded. Virtually all candidates understood what needed to be done but the percentage getting as far as 2.53×10^{13} J in part (a) must have been under 10%. Not only was there the 50 km^2 problem referred to above but also the problem of *h* in the p.e. = *mgh* equation. Far too many candidates simply put in 10 m when the required value is the height of the centre of mass of the water which is 5 m. Again it was apparent that candidates did not think about the size of their answer. For a huge amount of water and answer of 525 J is nonsensical, but so is 5.25×10^7 J. 50 million joules is only 14 kWh so experience would immediately recognise this as being wrong. Part (b) was answered rather better than part (a) but again it was the geometry which caused most problems. A sketch of a cylinder would have solved most of the difficulties but cylinders of length 20 m were common and so were volumes of spheres, and circumferences of circles. Area of a circle as $2\pi r^2$ featured frequently. The length of the cylinder as 3 m was often omitted completely. Part (c) produced a huge variety of answer quality. Answers that compared the two systems were equally acceptable with answers dealing with each separately. Many candidates concentrated far too much on wildlife and appearance. Some omitting completely the absence of greenhouse gas production, the need to reduce dependence on oil/coal, that the system has high capital costs and low running costs. Little comment was made about the problem that any tidal system will have (four) periods during any one day when no power output is possible and that these periods may occur at times of maximum demand. How much of an eyesore a barrage is compared with a tidal stream system is not so important. Lack of understanding of the problems was well illustrated by one candidate who gave as a drawback of the tidal stream that 'the blades will slow the water down'. In marking, lots of trivial answers did not score as well as good practical answers.

Question 5

5. (a) This question showed that many candidates understanding of electricity is very poor. The question did discriminate very well with many of the good candidates being able to score 8 – 10 marks. Weak candidates could not even give the difference between d.c. and a.c., frequently stating that a.c. changed from high current to zero many times a second. Electromagnetic induction caused lots of problems for many. The use of electric fields rather than magnetic fields was common and so too was the idea that the wire cutting a magnetic field had to have a current in it in order to produce an e.m.f. Many candidates used the equation $V = IR$ to explain why a high e.m.f. is needed. Their argument, seen far too often, was that a large value of *V* is required to get enough current to the consumer and since a power station can be a long way from the consumer there will still be enough voltage (or even current) left when it gets to the consumer. Only the better candidates used power = *VI,* so, for a fixed amount of power, by using a high value of *V* a low value of *I* can be used with consequent small power losses in transmission. Most candidates scored some marks on the behaviour of a transformer and were aware that it could change the voltage, provided a.c. was used. One example of misunderstanding of electricity is worth quoting in full. It was "An advantage of a.c. is that if it is not used up at a destination it can be recycled to be used somewhere else."

(b) 2 marks were scored here only if one of the reasons given was that by using overhead cables no insulation is required on the cable (and)/or that artificial cooling of the cables is not required. The other reason could have been one of a multitude of environmental/economic examples.

2826/03 Physics Practical

General comment
Just over four thousand candidates took the examination this summer, and the standard was generally good with scarcely any really poor candidates. No candidates appeared to be short of time. There were no known supply problems with the apparatus. This year question 1 scored higher marks than usual, question 2 was about the same, and the planning exercise was less well answered.

Question 1
The candidates were asked to find how the resistance of a 24W light bulb varied with the power supplied, and then to use a simple formula to estimate the filament temperature at full power.

Very few needed help with the construction of the circuit, and the table of results was generally completed well, with only a few in error using ln instead of log. Nearly every candidate correctly completed the column headings, and used consistent decimal places for the raw readings. Candidates were asked to estimate the largest % uncertainty in the current I; this was done well, but the commonest error was to quote ΔI as 0.005A rather than 0.01A (up to 0.05A) for a 2 d.p. raw reading. The mark scheme allowed ±0.001A for a 3 d.p. digital reading.

The quality of the results was more tightly judged this year. Any 5 out of the 6 plots on the graph were expected to be on a good straight line, within one small square. In trials the lowest voltage plot was found to be slightly off the line.

Graphs were well constructed and scales and axes usually chosen sensibly, with fewer awkward scales (e.g. 1 to 3) this year. Plotting errors were few, and were generally of the form where for example 1.1 and 1.01 were confused. Awkward scales often led to plotting errors. Most candidates are well able to find gradients and intercepts. In a few cases $y=mx+c$ led to $c = y/mx$ for the weaker candidates, but the commonest error was to select plots from the table of results that were not quite on the line.

The last part of the question asked for an analysis of the log graph and this separated out the weaker candidates. However, most knew that intercept and gradient gave lg(k) and n in the empirical relationship $P = k(R – R_0)^n$, but often could not say why. Candidates were then asked to explain why the graph supported the relationship, and to say that the log graph was a straight line was sufficient. Substitution methods were not accepted, and credit was lost if the graph was said to show proportionality.

The final part of the question quoted what was said to be a useful formula to estimate the filament temperature. As the formula nearly always gives an answer which is well above the melting point of the filament metal, perhaps it is not so very useful, but it proved a challenging exercise for quite a few candidates. A large proportion threw away marks by quoting the temperature to too many significant figures (2 or 3 sf was accepted).

Question 2
In this question candidates were asked to measure the period T of oscillation of a small bar magnet suspended by a thread h cm above another bar magnet on the bench.

In (b) (ii) marks were given for timing 10 or more oscillations to 1 or 2 decimal places. The few who attempted to time a single oscillation, or misread the stopwatch, lost both these marks.

(c) was the usual question about justifying significant figures (sf) used for the the period; the answer expected was to use the same sf as the raw data, with reference to decimal places losing credit.

In (d) credit was given for repeating readings, and most candidates did this.

In (e) candidates were asked to see if their results justified the statement that T is proportional to h. The recommended magnets, as used in trials, were not very strong, and the relationship was found to hold within 10%. Understandably, some centres used magnets that they had in stock, and some of these were clearly a bit stronger, and the oscillations at h = 6 cm were almost too fast to count, and in these cases it seems that T is not quite proportional to h. Credit was given for calculating the constants of proportionality and for arguing sensibly for either conclusion based on the data. In fact this part of the question was generally answered well.

Part (f) was the evaluation section out of 8 marks, and as usual this proved to be a challenge for many candidates. Those who had practised this question should have gained 4 marks straightaway. Two readings are not enough to form a conclusion (1 mark), so take more sets of readings and plot a graph of T against h (1 mark). It is difficult to time oscillations with a stop watch (human error in timing) (1 mark), so a fiducial marker should be used to aid timing (1 mark).

This year motion sensors and light gates were accepted as an improved method, but their positioning needed to be explained (1 mark). Alternatively, a high speed camera, with indication of time recording, was also accepted. However a large number of candidates are still stating vaguely that they would use a motion sensor with a data logger and computer, for no credit.

Other difficulties credited were the pendulum motion or wobbling of the suspended magnet, oscillations that were too fast to count, and problems in keeping the magnet level. Only a few mentioned that nearby iron objects such as clamp stands and bases could affect the system, and that wooden or plastic stands should be used. Scarcely any mentioned the effect of external magnetic fields such as the Earth's field.

Difficulties and solutions that were not credited were the presence of draughts, the solution often being to do the experiment in a vacuum. A large number wrote a great deal about the difficulty in measuring the height accurately and what they would do about it. In trials using a metre rule for this was found to present no problems at all.

The 2 marks given for spelling, punctuation and grammar were usually earned; most candidates make a decent effort to produce a presentable piece of work.

The Planning Exercise

The candidates were asked to plan an investigation to compare the efficiencies of photovoltaic solar cells and hot water solar panels, using laboratory experiments. A 150W light bulb was to be used as a source.

Experimental detail ranged from the careful to the inadequate. Only perhaps half the candidates included a load resistance in the solar cell circuit, and even fewer blackened the water pipes in the solar panel (or blackened the beaker of water) to make them efficient absorbers of radiation. The back of the panel was expected to be insulated to reduce heat loss. Some seemed quite impervious to the danger and impracticality of connecting voltmeter and ammeter to the 150W bulb mains circuit to check on its output power.

The calculations proved to be less of a problem and practically all quoted $P = VI$ and $E=mc\Delta\theta$ (usual notation), but some weaker candidates confused energy and power, or failed to define c, or failed to measure the mass or volume of the water. The best schemes used a continuous flow method for the solar panel. Nearly all candidates realised that cell and panel should be at the same distance from the light bulb, but fewer made the point that the absorbing areas should also be equal.

So far a reasonable candidate should have scored between 6 and 8 marks, which, added to the 4 marks nearly always added for references and quality of communication, would give 10 to 12 marks. But the extra 4 detail marks available proved very difficult to obtain. The commonest were, (a) the selection of a suitable load resistance in the cell circuit for maximum power output, (b) numerical evidence of preliminary practical work, and (c) a discussion of the different wavelengths required for solar cell and solar panel.

Other items on the mark scheme which were rarely or never put down were the comparable capital costs and payback times, the effect of the weather on outside installations, and a discussion of the optimum positioning of cells and panels outside.

Surprisingly some candidates still put no references. Those who do are usually now getting it right and putting in page numbers for book and internet sources. But should a reference really be needed for formulae such as P=VI ? Some candidates produced many pages of extracts from the internet as references; these are of little value and earn no credit.

Most scored the two marks for quality of written communication, except the few who wrote too much, and those who produced messy hand written work sometimes with no right-hand margin.

OCR instructs that the plan be attached to the test paper, with the test on top, and yet perhaps 20% of centres still put the plan on top, and thus give examiners a lot of trouble. Centres should also realise that it is often disadvantageous to the candidates not to include a supervisor's report, with a set of trial results. This was often missing.

Grade Thresholds

Advanced GCE Physics A (3883/7883)
June 2008 Examination Series

Unit Threshold Marks

Unit		Maximum Mark	A	B	C	D	E	U
2821	Raw	60	39	34	29	24	19	0
	UMS	90	72	63	54	45	36	0
2822	Raw	60	45	40	35	30	25	0
	UMS	90	72	63	54	45	36	0
2823A	Raw	120	99	88	77	67	57	0
	UMS	120	96	84	72	60	48	0
2823B	Raw	120	99	88	77	67	57	0
	UMS	120	96	84	72	60	48	0
2823C	Raw	120	94	85	76	67	58	0
	UMS	120	96	84	72	60	48	0
2824	Raw	90	58	51	44	38	32	0
	UMS	90	72	63	54	45	36	0
2825A	Raw	90	70	64	58	52	46	0
	UMS	90	72	63	54	45	36	0
2825B	Raw	90	69	62	55	48	41	0
	UMS	90	72	63	54	45	36	0
2825C	Raw	90	68	62	56	50	45	0
	UMS	90	72	63	54	45	36	0
2825D	Raw	90	63	56	50	44	38	0
	UMS	90	72	63	54	45	36	0
2825E	Raw	90	71	64	57	51	45	0
	UMS	90	72	63	54	45	36	0
2826A	Raw	120	87	78	69	60	51	0
	UMS	120	96	84	72	60	48	0
2826B	Raw	120	87	78	69	60	51	0
	UMS	120	96	84	72	60	48	0
2826C	Raw	120	83	76	69	62	55	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

Oxford Cambridge and RSA Examinations
is a Company Limited by Guarantee
Registered in England
Registered Office; 1 Hills Road, Cambridge, CB1 2EU
Registered Company Number: 3484466
OCR is an exempt Charity

OCR (Oxford Cambridge and RSA Examinations)
Head office
Telephone: 01223 552552
Facsimile: 01223 552553

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	19.2	35.7	53.2	70.0	83.2	100	7612
7883	28.0	50.1	69.6	85.9	95.8	100	5923

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.

Oxford Cambridge and RSA Examinations
is a Company Limited by Guarantee
Registered in England
Registered Office; 1 Hills Road, Cambridge, CB1 2EU
Registered Company Number: 3484466
OCR is an exempt Charity

OCR (Oxford Cambridge and RSA Examinations)
Head office
Telephone: 01223 552552
Facsimile: 01223 552553

OCR (Oxford Cambridge and RSA Examinations)
1 Hills Road
Cambridge
CB1 2EU

OCR Customer Contact Centre

14 – 19 Qualifications (General)
Telephone: 01223 553998
Facsimile: 01223 552627
Email: general.qualifications@ocr.org.uk

www.ocr.org.uk

For staff training purposes and as part of our quality assurance programme your call may be recorded or monitored

Oxford Cambridge and RSA Examinations
is a Company Limited by Guarantee
Registered in England
Registered Office; 1 Hills Road, Cambridge, CB1 2EU
Registered Company Number: 3484466
OCR is an exempt Charity

OCR (Oxford Cambridge and RSA Examinations)
Head office
Telephone: 01223 552552
Facsimile: 01223 552553