RECOGNISING ACHIEVEMENT

GCE

# Physics A

Advanced GCE **H558**

Advanced Subsidiary GCE **H158**

# OCR Report to Centres

# January 2012

**1640795970** **HX58/R/12J**

Oxford Cambridge and RSA Examinations

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

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## OCR REPORT TO CENTRES

# Overview

Centres have once again made good use of previous examiners' reports and examination papers. The quality of analytical work shows some improvement but candidates still have some way to go with learning definitions.

Candidates scored proportionate marks for questions requiring extended writing. Many candidates would benefit from sequencing the ideas in bullet points and making effective use of technical vocabulary. Too many candidates are still losing marks by not effectively scrutinising the questions.

A small, but growing number of Centres, entered their students for the G485 paper this session rather than in June 2012. The preparation from such Centres was generally good, but a significant number of the candidates lacked the sophistication and maturity to answer extended writing questions in Medical Physics and Nuclear Physics.

As always, experienced teams of examiners provided accurate and efficient marking. On screen marking of the four theory papers allowed analysis of the performance of the papers at a question-by-question level. Item level data available to examiners suggested that candidates had sufficient time to complete the paper. This was particularly noticeable in the A2 papers where an additional time of 15 minutes was provided.

The report for each unit of the Jan 2012 examination is given below.

# G481 Mechanics

### General Comments

The marks for this paper ranged from 0 to 60 and the mean score was about 34. It is good to report that most candidates made good use of their time and the omission rate for the questions was very low.

Candidates demonstrated good recall skills with definitions and it was clear that most Centres had made excellent use of past papers and mark schemes. The majority of candidates showed a slight improvement in the organisation of analytical solutions. The candidates were generally making better use of the Data, Formulae and Relationships Booklet. However, many descriptive responses still lacked structure and careful argument, often containing contradictions. The legibility of some candidates' writing remains a cause for concern.

There was sufficient time to complete the paper and even low-scoring candidates managed to attempt to answer most sections in every question.

### Comments on Individual Questions

### Question One

Most candidates made a good start by scoring more than seven marks for this opening question on the topic of motion.

**(a)** The majority of candidates effortlessly defined acceleration. Most candidates opted for '*change in velocity per unit time*'. Some decided to write a correct word equation. A number of candidates were exuberant with the use of the term 'per' and defined acceleration incorrectly as '*the rate of change of velocity per unit time*'.

**(b)** **(i)** Very few candidates struggled with determining the deceleration of the super-tanker and most scored three marks. A very small number of candidates used 40 minutes rather than 2400 s to determine the deceleration.

**(ii)** The majority of candidates successfully used equations of motion to determine the distance travelled by the super-tanker in 40 minutes. About a quarter of the candidates simply multiplied the initial velocity by the time of 2400 s to get an incorrect answer of 14400 m. A disappointing number also forgot to substitute a negative value for *a* into the equation $s = ut + \frac{1}{2}at^2$.

**(iii)** The candidates in the upper quartile drew correct shaped distance against time graph for the super-tanker. The majority of candidates were puzzled by the question. Among a number of different curves and straight lines, the most common incorrect answer was a straight line from the origin to (7.2 km, 40 mins).

**(c)** **(i)** The answers to **(c)** were very much Centre-dependent. The vast majority of candidates realised that the trolley accelerated down the ramp. Examiners allowed '*the trolley's speed increases as it moves down the ramp*'. A very small number of candidates thought that the trolley travelled down the ramp at constant speed because it '*had reached its terminal velocity*'.

**(ii)** The incorrect theme of terminal velocity was pursued by a minority of candidates. A good number of candidates realised that the trolley's acceleration was unaffected by its mass. Candidates either quoted this as a conclusion from Galileo's work or analytically showed that the acceleration down the ramp was a component of the acceleration of free fall.

**Question Two**

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

**(a)** The vast majority of the candidates gave a correct statement for the principle of conservation of energy. It was good to see statements such as '*the total energy of a closed system remains constant'* and '*energy cannot be created or destroyed – it can only be transformed into other forms*'.

**(b)** Most candidates quoted Nm or joule (J) as the unit for work done and were also successful with the definition for work done. Some candidates lost marks for failing to mention that there was movement in the direction of the force. A small number of candidates mentioned that work done was equal to change in energy. Although this statement is correct, it is not a definition.

**(c)** **(i)** Most candidates secured a mark by mentioning that the kinetic energy of the meteor was transformed into heat. A small number of candidates referred to gravitational potential energy being converted into kinetic energy and a significant number were of the view that most of the kinetic energy was converted into sound.

**(ii)** This was generally well answered with clear analytical work. Most candidates correctly started off with $8.4\times10^{16} = \frac{1}{2}mv^2$ and successfully showed that the speed of the meteor was about $2 \times 10^4$ m s$^{-1}$. About one in five candidates scored no marks.

**(iii)** About half of the candidates scored full marks and had the necessary skills to calculate the force either using the 'work done = kinetic energy' approach or determining the magnitude of the deceleration using $v^2 = u^2 + 2as$ and then using $F = ma$. A disappointing number of candidates determined the weight of the meteor and took this value as the force acting on the meteor during its impact with the Earth.

**Question Three**

All candidates attempted this question and scored marks covering the entire range. Most candidates scored 5 or more marks for this descriptive question. A significant number of candidates in the lower quartile misread **(d)** and gave answers in terms of thinking distance rather than braking distance.

**(a)** It is good to report that most candidates correctly drew a straight line graph passing through the origin. Inevitably, a small number of candidates either drew curves or a horizontal line confusing the sketch to be that for velocity against time.

**(b)** Most candidates realised that in the time taken for the driver to react, the car had a constant speed and this was illustrated by a positively sloping straight line graph.

**(c)** Most candidates gave a superb definition for braking distance**.** However, about a third of the candidates scored nothing for suggesting that the braking distance was '*the time taken for the car to stop while the brakes were applied'*.

**(d)** Most of the candidates correctly identified the two factors as the initial speed and mass of the car but few went on to discuss how these factors affected the braking distance. Only a small number of candidates mentioned how 'KE = work done', lead to the conclusion that the braking distance was directly proportional to the square of the initial speed. Very few candidates mentioned that the braking distance of the car was proportional to its mass. No credit was given for incomplete discussion points such as '*a heavy car takes longer to s*top' or '*more passengers in the car can increase the* braking *distance'*. A good number of candidates successfully opted to present their answers in bullet points. Some of the incorrectly identified factors were:

- age of driver
- condition of the driver due to drink or drugs
- reaction time of the driver
- shape of the car
- how hard the brakes were applied.

**(e)** Most candidates scored one or more marks for their descriptions. A small number of candidates wrote unnecessarily about accelerometers. A pleasing number of candidates realised that the seat belts increased the time taken for the driver to come to rest and this reduced the magnitude of the driver's deceleration. Some candidates went on to elaborate how the impact force was small using $F = \frac{m\Delta v}{\Delta t}$ or $\frac{1}{2}mv^2 = Fx$. Sadly, about a quarter of the candidates wrote a great deal but failed to secure any marks. No credit was given to answers that mentioned the effect of the width of the seat belts in reducing the pressure exerted on the driver in the collision.

**Question Four**

This was generally a well answered question with most candidates scoring more than four marks. Candidates showed good understanding of moments; this was particularly noticeable at the top end.

**(a)** More than half of the candidates successfully gave a robust definition for the moment of a force. The QWC mark was awarded for the correct definition and the correct spelling of the term 'perpendicular'.

**(b)** The majority of the candidates secured one or two marks for stating the correct conditions for equilibrium. No marks were awarded for vague answers such as '*equilibrium is when there is no motion*' or '*equilibrium implies no rotation and no acceleration*'.

**(c)** **(i)** This was generally well answered. However, a disappointing number of candidates gave incorrect definitions for centre of gravity. Two most frequently misquoted definitions were '*it is a point where the mass is located'* and '*it is a point where an object can be balanced*'.

**(ii)** Most candidates correctly determined the total clockwise moment to be 16.5 Nm. A small number of candidates lost a mark for calculating the force *F* and inserted the value of 412.5 N on the answer line.

**(iii)** The majority of the candidates found this question challenging. A significant number of candidates were clear that the anticlockwise moment was unchanged but few of them appreciated that the force *F* would increase because the perpendicular distance between the line of action of this force and the elbow decreased. A small number of candidates gave superb analytical answers in terms of resolving the force *F* perpendicular to the arm. The answer below was a typical response from such candidates:

$$F = \frac{16.5}{0.040 \times \cos\theta}$$

As the angle $\theta$ increases, cos $\theta$ decreases and therefore the force *F* increases.

**Question Five**

This question discriminated well. About a third of the candidates scored four or more marks and most candidates in the lower quartile worked productively through **(a)** and **(b)**.

**(a)** This 'show' question was correctly answered by almost all candidates. All candidates have a firm appreciation of the equation $W = mg$.

**(b)** About half of the candidates correctly determined the net force on the person to be 30 N and then went on to successfully determine the contact force *R*. Some candidates arrived at the correct answer by stating that the force *R* had to be greater than the weight by 30 N and hence *R* was then equal to the sum of the weight and the resultant force. Other candidates arrived at the same conclusion using the analytical approach below:

$$R - mg = ma$$
$$R = m(a + g) = 60 \times (0.50 + 9.81) \approx 620\ \text{N}$$

**(c)** A pleasing number of candidates realised that the force *R* was equal to the weight because the net force on the person was zero. Some candidates confused the physics altogether here by mentioning terminal velocities and drag. Surprisingly an answer such as '*the person reached terminal velocity because drag is equal to the weight'* was frequently encountered at the lower end.

**(d)** This question was only well answered by candidates in the upper quartile. Most candidates struggled to apply Newton's second law to the person in the lift and also struggled to use words to describe their physics. Ideas were jumbled up to the extent that it was impossible to untangle the physics. The modal mark for this question was sadly zero.

**Question Six**

This question was generally well answered. The omission rate for this question was zero. Candidates particularly showed a good understanding of Young's modulus.

**(a)** The majority of the candidates correctly stated Hooke's law. A very small number of candidates lost a mark for quoting the equation $F= kx$.

**(b)** **(i)** Most candidates knew that the gradient of the force against extension graph was equal to the force constant. About a quarter of the candidates gave incorrect answers, which included '*force constant is equal to the area under the graph'*.

**(ii)** This was generally well answered with most candidates identifying the area under the force against extension graph to be the work done on the spring. A disappointing number of candidates lost a mark for suggesting that '*work done on the spring = force × extension'*.

**(c)** Many candidates struggled to effectively communicate their ideas. A few candidates realised that the force acting on both springs was the same and this produced twice the original extension. Some candidates tried their luck by using the equation $\frac{1}{k} = \frac{1}{k_1} + \frac{1}{k_2}$.

Sadly, the vast majority of the candidates produced convoluted and contradictory explanations.

**(d)** **(i)** Most candidates correctly defined the Young modulus as the ratio of stress to strain and gave a plausible condition for its applicability.

**(ii)** The majority of candidates struggled to convert the cross-sectional area of the string from $mm^2$ to $m^2$. The most popular incorrect conversion factor was $10^{-3}$. In spite of this, many candidates secured one mark for their value for stress in **(ii)1**. The majority of the candidates went on to secure two further marks for their value of Young's modulus in **(ii)2**. The final part of the question on elastic potential energy was elegantly tackled by candidates at the top end. Some candidates started well with the correct equation 'energy = ½ *Fx*', but then went on to incorrectly substitute the strain value for the extension *x* or the Young's modulus value for the force *F.* A small number of candidates took a chance with the equation 'energy = ½ × stress × strain'.

# G482 Electrons, Waves and Photons

## General Comments

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

Good candidates were able to demonstrate their knowledge on the wide range of topics covered. Weaker candidates appeared to find the paper more accessible than previously resulting in few candidates scoring low marks.

On average the definitions of quantities were known better. However, there is still some confusion about when to use the words *displacement* or *amplitude*. There are still some very common but incorrect descriptions, for example, to refer to a transverse wave as *a wave which is oscillating at right angles to its direction*. The examiners are looking for reference to *the particles oscillating* in the case of a mechanical wave and *the direction of the wave motion/propagation/energy transfer* for the candidates to gain credit for their descriptions. In electricity topics too many candidates write about *current across* and *voltage through* or *voltage overcoming resistance* showing a lack of basic understanding of these words. *Voltage* and *p.d*. are still equated to *energy* and *force* in sentences where it would not happen when written in mathematical equation form.

There was sufficient time to complete the paper and weaker candidates managed to attempt to answer almost all sections in every question. Candidates scored freely in the first question where the exercise was mainly substituting into formulae and managing powers of ten. This proved to be a good introductory question easing them into the paper. This continued through the first parts of question 2 until the candidates were required to write sentences rather than just quote appropriate formulae and do calculations. The questions immediately became more discriminating. Again most candidates scored very highly in parts (b) and (c) in question 3. A number of sections within these three questions successfully differentiated between the different abilities. Parts of question 4 proved to be good discriminators as did part (c) of question 5. Most candidates were able to apply their knowledge of *polarisation* in question 6 to predict the outcome of the experimental situation described. In question 7 a significant number analysed the data relating to the photoelectric experiment correctly.

Most of the mathematical sections were well laid out. However some of the handwriting was difficult to decipher, often in cases where it was very small. Candidates should be reminded that the examiner has to read their answers on a computer screen.

## Comments on Individual Questions:

**1** **(a)** Very few failed to score this first mark

**(b)** Most performed the calculations correctly in (i) and (ii) with the correct power of ten. A few rounded down their answer in (i), so losing the second mark. In (iii) two common errors were to forget to convert to kilowatts and to multiply by the number of seconds in a day; both errors leading to very high costs in (iv).

**(c)** The majority completed this correctly, scoring full marks.

**2** **(a)** Many scored full marks. The most common error was to choose current as the quantity which is the same in a parallel circuit. They were able to calculate the resistance of one strip. Those, who could not, rarely made much sense of the rest of this section. The section proved to be a good discriminator with many scoring full marks

**(b)** Many candidates include resistance in their statement of Ohm's law. In this part and in question 7b a significant number did not understand that two variables are only proportional to each other when the graph goes through the origin. In this part the fact that the graph for R is a straight line is considered adequate to justify proportionality. In (ii) most candidates understood that they had to read data from the graph. However, a minority just gave a qualitative explanation that resistors in series need a larger voltage to achieve the current than resistors in parallel; there was no quantitative explanation. In (iii) most were aware that the current heated the thermistor causing the resistance to fall. However, the steady state situation was often omitted or not justified adequately to score the final mark.

**3** **(a)** Candidates must learn that *energy is transformed from other forms into electrical energy per unit charge;* not that *energy is given to each coulomb of charge*, nor the *energy needed to take unit charge round the complete circuit.* In (ii) internal resistance was mentioned by most but its role was not often explained clearly. Many also referred incorrectly to energy lost in circuit components and wires as a reason for reduced terminal p.d.

**(b)** The calculations were done well but few gave the answers as 6.0 and 2.0 ohms. There was no penalty on this occasion for writing the answers as 6 and 2 ohms.

**(c)** Most remembered to measure time in seconds achieving good if not full marks. The unit of charge was well known too.

**(d)** This question was a good discriminator with the vast majority describing the shape of the graph correctly but then only the better candidates writing clearly that the chemical energy in the cell is exhausted eventually so that the e.m.f. and current fall. Few mentioned internal resistance referring only to the constant load resistor which, commonly, overheated or fused causing the current to drop.

**4** **(a)** Most candidates were aware that waves carry energy but appear unaware that they also carry information through their shape. A few mentioned that matter or the medium was not transported with the wave or that the wave was propagated through the oscillations of the particles.

**(b)** This section discriminated well with only the better candidates scoring full marks. The average and weaker candidates stated that the *waves* oscillated rather than *the particles of the medium*.

**(c)** **(i)** Was explained well by most. Those who wrote of *bending* rather than *spreading* of the wave left open the possibility of refraction. In (ii), the experiment, the aperture was usually given suitable dimensions but the baffle in which it was situated was often far too small and placed too close to the loudspeaker resulting in little difference between the speaker aperture and the baffle aperture. Few stated clearly how the experiment showed that diffraction was taking place. Many candidates described a sound version of Young's slits experiment.

**(d)** The calculations were done well with most candidates scoring full marks. (ii) was a good discriminator. The most common error was to mix phase and path difference explanations of the maxima and minima. Another was not to give sufficient detail to score more than a single mark. In (iv) a significant number realised that the maxima and minima positions would be reversed but failed to state that the intensity of the maxima would be unchanged.

**5** **(a)** The two confusions here were to refer to the maximum displacement rather than amplitude for an antinode or to discuss the addition of two travelling waves.

**(b)** Candidates should be encouraged to use the word *reflected* rather than *bounced back*. Some described oscillations rather than a progressive wave travelling along the string.

**(c)** Part (iii) proved the most demanding and few candidates were able to give a convincing explanation as to why X and Z are in phase. Some candidates persuaded themselves through faulty arithmetic that all three points were the same distance from a node. However, these still scored the reason mark in (i). In (ii) a common error was to refer to speed and wavelength rather than treat frequency as an independent quantity.

**6** **(a)** Candidates showed their knowledge and scored freely in this section. Many repeated the question in (iii) rather than state that the most significant diffraction occurs for wavelengths of the order of the atomic spacing. Another misconception was to state that the X-rays could fit between the atomic layers.

**(b)** The disadvantage was well known. Those at a loss for an advantage suggested a sun tan as beneficial.

**(c)** A larger percentage of candidates than in previous examinations managed to score good marks for this calculation. A few used the correct formula but used the total energy rather than calculating the energy of one photon. Another incorrect approach was to try to use de Broglie's relationship.

**(d)** In (i) the correct symbol for a diode was not well known. Any candidate who drew an LED was awarded the mark. In (ii) the concept of polarisation is better understood by many but there are still those who try to answer the question as if the aerials are Polaroid filters. A minority considered that the detected signal continued to fall reaching zero at 180 degrees.

**7** **(a)** Most recognised that the photoelectric effect and Young's double slit experiments were the expected choices. The *gold leaf electroscope experiment* was not accepted as an answer.

**(b)** The word *minimum* was often omitted from the definition of work function. Some still believe that it is the energy to ionise an atom rather than to escape from the surface of the metal. In (ii) the organisation of the answer was often poor. Many tried to answer without quoting y = mx + c. Others linking the photoelectric equation with the above equation with loops to indicate which term corresponded to which without further explanation. This approach is really too cryptic to be rewarded with full marks. In (iii) there were some power of 10 errors and the reading of the x-axis intercept was often incorrect, stating $7.5 \times 10^{14}$ rather than $8.75 \times 10^{14}$ as the value. Many chose to substitute a point from the graph into the p.e. equation rather than multiply their first two answers together to find the work function. However, on average, the marks for (iii) were high.

# G484 The Newtonian World

**General Comments**

Candidates had, generally, been well prepared for this examination paper and were able to demonstrate their knowledge and understanding of the content of the specification. The spread of marks was from 0 to 58 with very few candidates scoring less than one-third of the available marks. Once again, the calculations were generally tackled more successfully than the questions requiring a written explanation where candidates tended to omit the technical detail that was required to score full marks. A significant number of candidates were careless in reading questions and consequently lost marks by failing to respond to the exact wording.

There was no evidence of candidates being short of time to complete the paper.

There still appears to be some misunderstanding regarding the use of rounding and significant figures in calculations. In most cases an answer is expected to 2 significant figures in standard form, unless the question specifically asks for a different accuracy. On many scripts intermediate values were quoted to eight or more significant figures; this not only wastes time but also increases the risk of incorrectly keying in the value to subsequent equations.

Some candidates failed to gain full marks when asked to show that a quantity had a given approximate value, eg Q3a(iv) and Q6b and c, because they either, did not state the accurate value to 2 or more significant figures, or did not show the full substitution into the equation. Good answers to calculations showed a logical sequence with clearly written digits particularly in powers of ten.

**Comments on Individual Questions**

**1** **(a)** **(i)** Most candidates got off to a good start with this question although a minority gave a “conservation of momentum” answer.

**(ii)** A significant number scored two marks here. However some candidates only gave the single statement that momentum had magnitude and direction. Candidates are reminded that the number of marks allocated to a question is a good indication of the amount of explanation required.

**(b)** This question caused little difficulty for the vast majority of candidates. They correctly linked the given energy to the kinetic energy of the car and calculated the maximum speed accurately. Only a small minority converted MJ to J incorrectly.

**(c)** Most candidates used the correct formula for momentum. A significant minority failed to use the combined mass for the momentum after the collision. A significant number gave their answer as 3.12 m $s^{-1}$ despite quoting the correct intermediate equation.

**2** **(a)** The vast majority of candidates gave the correct values for amplitude and period and were able to use the period to correctly calculate the angular frequency.

**(b)** The answers to this fairly searching question were quite pleasing in general. Few candidates were put off by the three answers being at the equilibrium position. Most candidates complied with this instruction to use a cross to indicate the location of their point. However a small number marked their points with a dot. This did cause some problems to examiners as the scanning process makes it difficult to detect a small dot unless it is ‘circled’. Candidates are advised to follow instructions carefully when marking points onto diagrams.

Most were able to score two out of the three marks with the most common error being the positioning of the point A at maximum displacement.

**(c)** **(i)** This straight forward calculation rarely caused problems for the majority of candidates. The main errors that were seen involved the power of ten used for frequency and conversion of the amplitude from mm to m. A significant minority quoted the correct formula but then forgot to square the angular frequency.

**(ii)** Most found this very difficult. The most common error was the use of $P = Fv$ with the maximum velocity formula for SHM from the data book. Few realised that this question involved the use of the mean damping force and that SHM formulae were therefore irrelevant. Only the most able candidates recognised the need to calculate the work done against the damping force using an appropriate distance, usually the amplitude, and so score the first mark. Only rarely was this distance then linked to the corresponding time to calculate the mean power.

**3** **(a)** **(i)** Most candidates scored this mark easily. Incorrect spelling of 'geostationary' was a rare occurrence.

**(ii)** The significance of an equatorial orbit was obviously not realised by a significant number of candidates, and this inevitably led to confused answers.

**(iii)** Even with correct answers to (ii), many failed to grasp the idea of this question. Only a minority gave an answer linked to the receiving dish/aerial.

**(iv)** The majority of candidates selected the correct equation and substituted the given values to obtain the correct radius.

**(b)** **(i)** Kepler's law was well known to the majority of candidates although some lost the mark because they gave a relationship involving symbols without defining their meaning.

**(ii)** Very few attempted to use the answer to 3b(i) to set up the ratio. The majority calculated the radius of the Moon's orbit and then evaluated the ratio. This obviously involved extra working with consequent risk of arithmetical errors.

**4** **(a)** The majority of candidates scored this mark by referring to the 'latent heat of fusion' although a small number were unable to spell fusion correctly. There were only rare confusions with vaporisation.

**(b)** **(i)** The majority knew that the internal energy was the sum of kinetic and potential energies but a significant number did not refer to molecules and or the random distribution and consequently could only score one mark.

**(ii)** This was not well known or well described by a large number of candidates. Common misconceptions were kinetic energy increasing or potential energy changing to kinetic energy. The examiners recognised that some candidates would interpret the question as requiring a reason for the increase in potential energy and so gave credit for accurate comments relating to the work done to break or increase the length of intermolecular bonds.

**(c)** **(i)** Most managed to score full marks in this calculation. A small number lost one mark in calculating the mass of air. A similar number could not correctly calculate the energy lost in one hour from the given power value.

**(ii)** Most candidates were able to quote one reason but could not find a second reason or failed to express their ideas with sufficient clarity to earn the second mark.

**5 (a) (i)** Most correctly stated the meaning of an elastic collision although some unfortunately forgot to specify that it was *kinetic* energy that must be conserved.

**(ii)** Very few candidates managed to score more than half of the available marks largely as a result of failing to concentrate on the origin of the force on the walls of the container. All too often the answers were vaguely worded descriptions of kinetic theory with a passing reference to moving molecules hitting the wall with a force. It was hoped that the first and last marking points on the scheme would be accessible to most candidates but in reality only the last point was regularly scored. Even this point was lost by a significant number because they failed to identify the symbols used in their formula. Candidate should realise that "explain" in an A2 question is a prompt to provide clear scientific reasons for statements rather than colloquial comments.

**(iii)** The majority of candidates stated correctly that the molecules would travel faster (on average) and a significant number went on to explain that either the momentum change would be greater or that there would be more collisions per unit time. A minority omitted to refer to the time element involved and were not able to score this mark.

**(b) (i)** Generally well answered. Only a small minority did not convert the temperatures into kelvin nor react to the negative pressure that this error created. A few started with an incorrect equation or failed to rearrange the equation correctly.

**(ii)** Most had the correct idea and scored the mark although precise reasoning was rarely seen.

**6 (a)** This was well answered with only a small number of numerical errors.

**(b)** Most candidates selected the correct equation, showed clear substitution of the values and correctly evaluated their expression to give $2.3 \times 10^{-20}$ J. As this was a "Show" question these intermediate steps were necessary to score full marks.

**(c)** Another question to which candidates were able to give good answers. Good answers showed the initial equation, correct substitution, transposition and evaluation to 2 significant figures in a clear, logical sequence.

**(d)** This question troubled all but the most able candidates. It was rare to see a clear reference to the range of molecular speeds. Common errors seen were;
"The mass of helium atoms is so small that they are not affected by the force of gravity"; "the gravitation field of the Sun/Moon pulls the helium atoms out" and "gravity is too weak in the upper atmosphere".

# G485 Fields, Particles and Frontiers of Physics

**General Comments**

The marks for this paper ranged from 3 to 91 and the mean score was about 60. Almost all candidates managed to finish the paper in the scheduled time of 2 hours. The omission rate was significantly less than the paper last session; even low-scoring candidates managed to attempt to answer most sections in every question.

A few Centres had entered their students for this large unit in the January session rather than in the June session. The responses were generally of appropriate A2 standard, with many candidates demonstrating decent analytical skills. There was some evidence that candidates lacked maturity when answering questions on medical physics and nuclear physics. Some Centres had done a great job in preparing their students to tackle the complexities of this paper. Examiners would still advise the majority of Centres to enter their students in the summer.

There was a marginal improvement in the quality of extended writing. Some candidates would have done better by writing their answers in bullet points because this would have avoided contradictory statements. The understanding of logarithms was generally quite good. This was particularly noticeable in the **Q4(c)(iii)** where some candidates correctly determined the time constant using values from the graph and solving the equation $V = V_0 e^{-\frac{t}{CR}}$. Candidates once again showed their enthusiasm for topics on particles physics and cosmology by providing robust answers and generally scoring high marks.

A small number of candidates still disadvantage themselves by using handwriting that is idiosyncratic to the point of illegibility. Centres should encourage such students to develop a style of handwriting intended to be read by examiners.

About a quarter of the candidates were resitting this paper.

**Comments on Individual Questions**

**1** Most candidates made a good start by scoring five or more marks for this opening question. The synoptic elements in **(b)(ii)** and **(b)(iii)** were generally well tackled by the majority of the candidates.

**(a)** The majority of candidates effortlessly defined electric field strength. Some opted for a word equation. It was good to see reference to a 'positive' charge in the definition. A small number of candidates gave vague answers such as '*it is the force experienced by a charge in the field*'. Some candidates incorrectly quoted '*voltage/separation'* as the definition for electric field strength.

**(b)** **(i)** The vast majority of the candidates correctly calculated the potential difference across the electrodes using the equation $E = \frac{V}{d}$. A tiny proportion of the candidates could not rearrange this simple equation.

**(ii)** Most candidates skilfully determined the charge transferred between the electrodes. A small number of candidates struggled to determine the number of electrons transferred. The most common error was to divide the charge by the mass of the electron.

**(iii)** It was good to see a variety of methods used to determine the energy transferred. The most popular route was to use 'energy = p.d × charge'. Candidates also successfully used 'energy = *VIt*'. Less than half of the candidates incorrectly tried to use $E = \frac{1}{2}QV$ or calculated the power instead of the energy transferred by the electrons.

**2** This question produced a full range of marks. Most candidates did well with **(c)(i)** and **(c)(ii)** and a significant number of candidates had simply forgotten about torque of a couple.

**(a)** The vast majority of candidates failed to give a proper definition for torque of a couple. Most answers were defining either a couple or moment due to a single force. It is interesting, that in spite of an incorrect definition, some candidates successfully managed to calculate the torque in **(b)(ii)2**.

**(b)** **(i)** About two third of the candidates correctly identified the direction of the force on the wire to be '*into'* the plane of the paper. The rest of the candidates incorrectly opted for '*out of paper*'.

**(ii)** Almost all candidates managed to calculate the force experienced by the length AB in **(ii)1**. There were mixed fortunes with the calculation for torque. A disturbing number of candidates used twice the length; some even decided to go for the total length of the rectangular coil.

**(c)** **(i)** It was great to see the majority of candidates correctly use the equation $F = BQv$ to calculate the charge *Q*.

**(ii)** The answers to this question were generally well laid out. Most candidates secured full marks by either using $F = \frac{mv^2}{r}$ or $r = \frac{mv}{BQ}$. Inevitably, some candidates struggled to rearrange the equations to find the radius. There were also some strange attempts to use $E = \frac{kQ}{r^2}$ to find the radius *r*. Such wayward answers showed how inadequately prepared some of the candidates were to tackle this A2 paper.

**(iii)** Many candidates realised that the mass of oxygen-18 was more than that of oxygen-16. However, their reasoning as to why the oxygen-18 ion described an arc of greater radius, lacked depth and understanding. Momentum and kinetic energy were some of the quantities used unsuccessfully to explain the effect on the radius of the ion. A good number of the candidates in the upper quartile skilfully used $r = \frac{mv}{BQ}$ to justify that the radius *r* was directly proportional to the mass *m* of the ion.

**3** A significant number of candidates struggled with this question on electromagnetic induction. Many candidates could recall Faraday's law of electromagnetic induction, but lacked the skill to apply it in **(b)**. There was a slight improvement in the understanding of the terms *flux* and *flux density*.

Most candidates successfully defined magnetic flux density. Some candidates lost a mark for not mentioning that the area had to be normal to the magnetic field. A disappointing number of candidates, about a third, scored nothing for comments such as '*it is equal to the number of magnetic field lines linking the circuit*' and '*it is the strength of the magnetic field*'.

**(b)** **(i)** The modal mark for this question was zero. Many candidates correctly quoted Faraday's law of electromagnetic induction, but failed to adequately apply it to the circuit. About a third of the candidates realised that between $t$ = 0 s to 2.5 s, the rate of change of magnetic flux was constant. No marks were awarded for identifying the graph to be a straight line. A significant number of candidates used the term *magnetic field strength* rather than *magnetic flux density* in their descriptions; the use of the latter term should be encouraged.

**(ii)** There was lots of confusion here. Only a quarter of the candidates, mainly at the top-end, managed to secure three marks. A disturbing number of candidates mentioned Faraday's law and then went on to equate the gradient of the graph in Fig.3.2 as the value of the e.m.f. A significant number failed to take account of the 180 turns or could not calculate the cross-sectional area in square metres.

**(c)** **(i)** Candidates generally showed a good understanding of transformers; about half of the candidates gained full marks. A small number of candidates had problems rearranging the turn-ratio equation. The most common incorrect answer for the current was 100 A.

**(ii)** Sadly, the modal mark for this question was zero. A disturbing number of candidates thought that the battery would run out of energy. Some answers, such as '*a transformer needs alternating current to work*' were seen as an act of desperation. About a third of the candidates realised that the p.d. across the lamp would be zero because there '*was no change in the magnetic flux in the secondary coil'*.

**4** Candidates showed a good understanding of capacitors. The analytical solutions were generally well laid out and candidates had the confidence and the skills to use natural logs in **(b)(iii)1**.

**(a)** The majority of candidates gave perfect definition for capacitance. No credit was given if the definition was a mixture of a quantity and a unit; hence an answer such as '*charge per unit volt'* was simply wrong.

**(b)** **(i)** Most candidates successfully showed that the total capacitance of the circuit was 80 $\mu$F. The answers were well structured and showed good understanding of series and parallel combinations.

**(ii)** This was a well answered question with the majority of candidates scoring full marks. A small number of candidates either missed out the $10^{-6}$ factor for the $\mu$ or missed out squaring the p.d. when using the equation $\frac{1}{2}V^2C$ .

**(iii)** Candidates generally demonstrated good understanding of time constant. Most candidates were familiar with the idea that after a time equal to the time constant, the p.d. across the circuit would decreases to $e^{-1}$ or 37% of its initial value. An amazing number of candidates had the skill to use the equation $V = V_0 e^{-\frac{t}{CR}}$ and points from the graph to show that *CR* was about 20 s. Most candidates also successfully calculated the resistance *R* of the resistor to be 250 k$\Omega$.

**5** This question produced a good range of marks; most candidates scored ten or more marks. The answers were generally well structured and showed a good understanding of radioactivity decay.

**(a)** Most candidates knew that isotopes have the same number of protons. Answers such as '*isotopes have different number of neutrons*' and '*isotopes are chemically the same*' were not allowed.

**(b)** The questions referred to both protons and neutrons, but a significant number of candidates mentioned the electrostatic force. The majority of the candidates recognised the two fundamental forces experienced by the particles to be the strong nuclear force and gravitational force.

**(c)** **(i)** Most candidates had no problems with this question and managed to correctly determine the nucleon and proton numbers for the nitrogen nucleus.

**(ii)** This was superbly answered, with most candidates recalling that a down-quark transforms into an up-quark. About a third of the candidates misread the question and mentioned transformation of a neutron into a proton.

**(d)** **(i)** This synoptic question about the maximum speed of the emitted electron from the carbon-14 nucleus was generally well answered. However, a large number of candidates failed to convert the kinetic energy of 0.16 MeV in joules and ended up with unrealistic values for the speed of the electron. Some candidates were unperturbed by a speed of $5.9 \times 10^{17}$ m s$^{-1}$ when using 0.16 as the kinetic energy of the electron.

**(ii)** Not many candidates realised that the mass of the fast speed electron would have been greater than its rest mass. A disturbing number of candidates concluded that the actual speed of the emitted electron would be less because of '*collisions with air molecules*'.

**(e)** **(i)** Most candidates correctly calculated the decay constant in s$^{-1}$. A very small number of candidates got an answer of $1.25 \times 10^{-4}$ because of failure to convert the half life into seconds. Candidates are reminded that the conversion factor from years to seconds is given in the Data, Formulae and Relationships Booklet.

**(ii)** A significant number of candidates struggled to show that 1.0 mg of carbon-14 had $4.3 \times 10^{19}$ nuclei. Some candidates used elaborate routes to get close to the correct answer. Some candidates decided to use the mass of the nucleons and totally ignored the molar mass given in the question.

**(iii)** Candidates showed familiarity with the equation $A = \lambda N$ and effortlessly used it to calculate the activity of the source.

**(f)** This was poorly answered question with most candidates not understanding the role of carbon-14 or the processes involved in determining the age of the relic. The modal mark was zero and less than a quarter of the candidates managed to score three of more marks. Many candidates failed to mention that one of the limitations of this technique was that the activity from the relic was masked by background radiation. Some of the most common misconceptions were:

Carbon 14 decays into carbon-12.

Carbon-14 was produced after the death of a tree.

The decomposition of carbon-12 was used to determine the age of the relic.

**6** This was a discriminating question, with many of the candidates in the upper quartile scoring close to maximum marks.

**(a)** Many candidates knew that binding energy was something to do with the breaking up the nucleus. Sadly, a significant number of candidates did not mention that this was the **minimum** energy required to break up the nucleus into its constituent nucleons. A full explanation of binding energy in terms of mass defect was acceptable. The modal score was zero with about a third of the candidates scoring full marks.

**(b)** **(i)** Candidates would have struggled if this was not a 'show' question. Binding energy per nucleon was not a familiar concept to about a third of the candidates. It was clear that some candidates eventually got the right answer by trial and error.

**(ii)** Showing that the power radiated from the Sun's surface was $4.0 \times 10^{26}$ W turned out to be an immense task for many candidates. Some candidates tried using $\pi r^2$ instead of $4\pi r^2$ in their analysis. A significant number of candidates did not fully comprehend the term intensity. The final part of the question was generally well answered with candidates using the answers from **(b)(ii)1** and **(b)(i)**. A small number of candidates used $1.1 \times 10^{-12}$ J instead of $3.7 \times 10^{-12}$ J when estimating the number of reactions per second.

**7** This question produced a good range of marks from 0 to 9. Candidates in the lower quartile struggled to give precise answers in **(d)**.

**(a)** Most candidates either scored one or two marks. Candidates were familiar with high-speed electrons hitting a metal target. Some even mentioned how decelerating electrons produced X-ray photons. About a third of the candidates wrote lots but their statements lacked clarity and precision.

**(b)** **(i)** A range of answers was allowed for the definition of a photon. It seemed that many candidates had remembered '*a photon is a packet of electromagnetic energy*' from Unit G482.

**(ii)** Many candidates mentioned wavelengths or frequencies but the statements lacked adequate explanations. Successful answers were those that mentioned either $E = \frac{hc}{\lambda}$ or $E = hf$ .

**(c)** About a third of the candidates produced well structured and reasoned solutions. Weaker candidates were confused and could not see the importance of 120 kV.

Some candidates substituted $120 \times 10^3$ as the value for *E* in the equation $E = \frac{hc}{\lambda}$ .

**(d)** Compton effect was the most popular answer. A pleasing number of candidates knew that the scattered photon had lower energy and an electron was ejected from the atom. However, candidates who decided to go for this interaction mechanism had to work much harder to gain two marks than those who opted for pair production.

**8** Many candidates lost marks for their poor descriptions of the gamma camera components in **(d)** and the Doppler Effect to find the speed of blood in **(d)(ii)**. Candidates are once again reminded that they can maximise their marks by focusing on key points and presenting their answers succinctly as bullet points.

**(a)** A question similar to this has appeared in a previous paper, so some candidates produced perfect and well rehearsed answers. About a third of the candidates scored nothing, but wrote many sentences. A large number of candidates thought that non-invasive technique was one where no ionising radiation was used.

**(b)** Many candidates were familiar with the medical tracer technetium-99m, although most of them could not spell the name of the tracer correctly. Iodine was another commonly mentioned tracer. Amazingly, many candidates failed to mention that the tracer was somehow inserted into the patient. A disappointing number of candidates hedged their bets by mentioning barium and then even went on to describe how it produces amazing X-ray images.

**(c)** This proved to be a challenging question. Candidates had superficial knowledge of the key components of the gamma camera. Answers lacked robustness. The language used to describe the components lacked precision. For example, '*tiny specks of light*' was used instead of '*photons of light*' and '*data'* was used instead of '*electrical signals from the photomultiplier tubes'*. Most candidates successfully explained the role of the collimator. The role of the scintillator and the photomultiplier tubes were really misunderstood. The scintillator was incorrectly mentioned as '*changing gamma waves into data*'. Very few candidates realised that the photomultiplier tubes changed photons of light into electrical signals which were processed by the computer to produce an image. Once again, some candidates would have benefitted from presented their answers in bullet points and focusing on the accuracy of their physics.

**(d)** **(i)** Most candidates effortlessly calculated the wavelength of the ultrasound. The modal score for this synoptic question was two marks.

**(ii)** Many candidates confused this question with A-scans. A disappointing number of candidates failed to mention that the ultrasound was reflected by the blood cells. Some candidates in the upper quartile appreciated that the moving blood cells were responsible for changing the wavelength of the reflected ultrasound and the change in the wavelength was related to the speed of blood. Candidates did not score any marks for simply mentioning the Doppler Effect. About a third of the candidates scored two or more marks and the modal mark was zero.

**9** This was a high scoring question with most candidates answering all the questions. Candidates always enjoy answering questions on cosmology and this was no exception. The majority of candidates scored more than half of the marks.

**(a)** The description of the formation of the Sun was elegantly sequenced. Some candidates showed an understanding beyond the confines of the specification. More than half of the candidates scored full marks. This was definitely a success story for the candidates.

**(b)** This was generally well answered with most candidates knowing something about white dwarfs. Many candidates mentioned that the white dwarfs were extremely hot and dense. Some even mentioned Chandrasekhar's limit and how electron degeneracy prevented its collapse. About a quarter of the candidates scored nothing and produced answers that were simply incorrect. Some candidates mentioned more than two properties and put themselves in danger of contradictory answers.

**(c)** **(i)** The majority of candidates either described a flat universe or simply stated '*flat universe'*. About one in five candidates gave contradictory answers or opted for the open universe.

**(ii)** It was good to see candidates correctly using the equations from the Data, Formulae and Relationships Booklet to determine the critical density of the universe. A small number of candidates spoilt their answers by squaring the term $3H_0$ instead of just $H_0$ in the critical density equation $\frac{3H_0^{\ 2}}{8\pi G}$.

**(iii)** This was generally well answered with many candidates scoring full marks. About a third of the candidates scored nothing, many of whom determined the volume occupied by a single proton – about 0.17 $m^3$.

**(d)** This was a challenging end to the paper. About one in five candidates realised that the speed $v$ of the electron was given by the equation $\frac{1}{2}mv^2 = \frac{3}{2}kT$ and hence the ratio of the speeds was simply $\sqrt{\frac{10^8}{2.7}}$. Many candidates thought that the ratio of the speeds was the ratio of the temperatures.

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