Oxford Cambridge and RSA

# GCE

# Physics B (Advancing Physics)

Advanced GCE **H559**

Advanced Subsidiary GCE **H159**

# OCR Report to Centres June 2014

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

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

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

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## Advanced Subsidiary GCE Physics B (Advancing Physics) (H159)

## OCR REPORT TO CENTRES

# G491 Physics in Action

### General Comments:

Timing was an issue for some candidates on this paper, which may have been slightly more demanding than some previous papers in the series. Some candidates seemed thrown by a slightly new context, the digital QR codes in Q.10, but they should expect to apply their physics knowledge (digital information) to novel contexts in the examination. The hardest questions did come at the end of the paper Q.10ci,ii,iii were the last questions and many weaker candidates had run out of thinking time at this stage and sadly made little attempt. These questions about a lens forming an image of a QR code relied on students thinking through the problem rather than a formulaic approach. Those that used the concept of magnification before automatically trying the lens formula were well rewarded, as no hints or structure to the solution were given. Some questions earlier in the paper also suffered from lack of response: e.g. Q.3c on bandwidth and Q.9biii on the strength of a graphene nano-layer.

There were some pleasing answers to short calculation questions on electrical problems Q.5 and Q.6, although POT (Power of Ten) errors were more common on the calculations in Q.9 involving the nano-scale of graphene. There were many good diagrams of wavefronts being focussed by a lens Q.7, but circuit diagram symbols Q.8a were not so well remembered. Explaining the physics they know, remains a problem for some candidates and some contradict themselves in later sentences in a paragraph, nullifying good work. This was particularly noticeable in Q.8aii on explaining the action of a potential divider, although many could go on in Q.8biii to perform a calculation based on the divider. Overall the mean mark this session had dropped to nearer half the paper total, but there was a good spread to the paper marks.

### Comments on Individual Questions: Section A (22 marks)

Q.1 This question concerned selecting the correct units for the quantities: frequency, lens power and charge carrier density. The units of frequency ($s^{-1}$) were most often given correctly, than lens power ($m^{-1}$). A very common error was to choose ($kg\ m^{-3}$) the units of mass density for charge carrier density which is number per unit volume ($m^{-3}$).

Q.2a This question concerned describing important features of a sound waveform. In general candidates were weak at articulating their understanding. The better candidates realised the importance of regular intervals in time as being the key to recognising a definite pitch. Some mistakenly interpreted the graph as a frequency spectrum, describing what all the amplitudes and frequencies were doing, clearly thinking that these were readily visible features and scored no marks. Mentions of lengths or wavelength were also penalised.

Q.2b Here candidates had to calculate the frequency of the fundamental. The best counted the wave intervals rather than peaks and divided to find the time period per wave and then found the reciprocal. Because of this miscounting, many calculated the frequency at 300Hz but this was outside the accepted limits deliberately set at 270 to 280 Hz. Weaker candidates missed the millisecond time units and made POT errors.

Q.3a Nearly all students knew that analogue signals need to be sampled at twice the highest frequency present to digitise them satisfactorily, and got the correct answer at 12 kHz.

Q.3b Most candidates knew to take $\log_2$ (total noisy signal range / noise range). The most common errors were to quote meaningless fractional bits (8.6) in the final answer or to round down to 8 bits, rather than the correct answer of 9 bits.

Q.3c This question asked how to estimate the bandwidth needed to transmit the digitised information. Many good candidates realised this was approximately the bit rate (first mark) and decided to calculate it, although this was not strictly necessary, and got full marks for:
12000 samples per second x 9 bits per sample = 108000 Hz.
This was also available to those who stated multiply sampling rate x bits per sample, who scored both marks. Weaker candidates made a great variety of errors, most common was to confuse the bandwidth of the transmission signal with the bandwidth of the sound signal, e.g. highest minus lowest frequencies present in the signal, which scored no credit.

Q.4 This was a new style of Fermi type question asking candidates to make sensible order of magnitude estimates of quantities they should be familiar with to the nearest 3 orders of magnitude from a list offered. The quantities were the density of wood (should be similar to water $10^3$ kg $m^{-3}$), the mass in kg of a 1 mm diameter raindrop ($10^{-6}$ kg) and the wavelength of infra red radiation in m ($10^{-6}$ m). Candidates are not supposed to memorise such values as these, but be able to make sensible estimates in appropriate metric units from their own experience and knowledge. Most candidates made a brave attempt at all three, and the facility was about a half from the list of 5 orders of magnitude. This is a lot better than guesswork, but it showed surprisingly only a little differentiation. The most common error was to believe that infra red has much too long a wavelength of the order of long radio waves (about $10^6$ m).

Q.5 This question asked for the number of electrons passing a point per second for a current of 8.0 pA. Most candidates correctly divided the charge per second by the charge per electron ($N = I / e$) to get the electrons per second at 5.0 x $10^7$ for 2 marks. Wrong answers were most often POT errors or had missed pico = $10^{-12}$ altogether and could score 1/2 marks. A few quoted the inverse of the correct answer (2.0 x $10^{-8}$ seconds per electron) and scored zero if they did not realise what they had calculated and take the inverse. It might help weaker candidates to write word unit equations to keep track of what they are calculating if they cannot handle full quantity calculus, when performing relatively unfamiliar calculations.

Q.6 This question was two short calculations about a wire wound resistor, and candidates coped very well. In a) they had to calculate the maximum operating power, given $R$ and $V$. Most candidates sensibly calculated $V^2 / R$ in one bite, to get 31 W for 2 marks. Some calculated current first from $V/R$ for a first mark and then proceeded to find power as $I\,V$ for the second mark. Some did not secure the second mark due to gross rounding errors (RE) from their current value.

In b) they were asked to calculate the length of wire of given cross-section and resistivity. This was equally well answered, re-arranging for $L = RA / \rho$ for the first mark and calculating 0.19 m for the second. Here there were a few POT errors or RE (if they had not been penalised already for RE – only one application of penalty per paper) but most got the 2 marks.

Q.7a On the whole drawing skills have improved, with the majority of candidates keeping the wavelength between wavefronts sensibly constant. There was appreciated evidence that some Centres had encouraged measurement of the wavelength and use of guidelines to the further focus point, those that tried this usually scored full marks. Most who had an incorrect shorter focal length, also compressed the wavelength so losing both marks.

Q.7b) Most stated correctly that the lens power was less, but the mark was for the explanation. Many used less curvature added by the lens which was pleasing, but also light being slowed / refracted less by second lens gained the mark. A few had not read the question fully giving no explanation and some gave an explanation and then contradicted themselves, not scoring the mark, (e.g. lens adds less curvature making focus point nearer the lens – scored zero).

Section B (38 marks)

Q.8 This question was about an LDR light sensor in a potential divider circuit. There was evidence that some candidates did not read the question carefully enough.

8ai Candidates were asked to draw a potential divider circuit diagram and to label the fixed resistor R and the LDR. Few labelled anything, so this rubric was overlooked in the mark scheme. Even so a surprising number did not know the circuit symbol for an LDR (although this was generously widened to include variable resistor and general transducer symbols). Some drew correct components, but connected in parallel, scoring zero. The facility of this question was surprisingly under a half.

8aii This was an intentionally differentiating question asking candidates to explain the potential divider and why the voltmeter should be placed across the fixed resistor. Top grade candidates confidently talked about the changing resistance ratio and voltage ratio, specified the sense of the change and mentioned one of the potential divider formulae with appropriate proportionality discussion for full 3 marks. Weaker candidates had lots of opportunity to make incorrect statements or contradict something of value they had already mentioned. Some common errors were: the current is always constant (in a series circuit), when LDR decreases resistance the fixed R increases resistance (to keep the current constant), p.d.s referred to as flowing through resistors etc. The easiest mark to score was for the idea that the two series resistors shared the total p.d. and many weak candidates did get this far.

8bi This part asked for a definition of sensitivity, but many candidates chose to describe how sensitivity changes as light intensity increases, taken from Fig. 8.2, even though they went on in bii to calculate sensitivity correctly. (This was probably because a recent past paper had asked something similar? – again candidates should be encouraged to read key words in the question very carefully). The easiest way to get the mark was to say sensitivity is the gradient of the graph, or any mathematical equivalent involving $\Delta y / \Delta x$.

8bii Here candidates had to calculate the sensitivity by drawing a tangent to the graph at 1000 lux and getting the tangent slope from a suitably large triangle (base size greater than 400 lux). Too many candidates evaluated y / x = 3.8/1000 V $lux^{-1}$, at 1000 lux, having written change in V / change in intensity, or are they taking 'change in' measured from the origin? Anyway, these scored zero showing no understanding of local gradient of a graph. Those that drew small tangential triangles or even small chords centred on 1000 lux could gain partial credit. The accepted values were in the range (1.0 to 1.4) x $10^{-3}$ V $lux^{-1}$ and could score up to maximum 3 marks if their method was correct.

8biii This was a relatively tough calculation based on the potential divider, to find the resistance of the LDR at 1000 lux intensity, and ended with a facility over a half which was encouraging. Most got the first mark for correctly reading 3.8 V output at this intensity from the graph. Many then got only one further mark by mixing up the R and the LDR in the potential divider formula and getting around 1400 Ω, or by correctly getting the LDR voltage at 2.2 V. Those that kept a grip to get 460 Ω could secure a further 3 marks. Other partway marks could be obtained for getting the correct current at 4.8 mA. Several used resistance ratio arguments to correctly get 1260 Ω for the total circuit resistance, but didn't realise what they had found! (should then subtract the 800 Ω of the fixed resistor). It was a good differentiating question with something for candidates at all levels.

Q.9 This question gave details and a nano-image of graphene a new material based on a single layer of bonded carbon atoms.

9ai Here candidates had to show that the mass of a 1 $m^2$ area of graphene is about $10^{-6}$ kg, by scaling a nano-image of about 60 carbon atoms. The facility was well over a half which was pleasing, better candidates found the mass of 60 carbon atoms and scaled up by $(10^9)^2$ for the number of $nm^2$ in 1 $m^2$. Weaker candidates juggled numbers to try to get near the 'show that' value, with much misuse of the equals sign, squaring of 60 atoms, or not squaring the $10^9$ factor for the area ratio. Several part marks were available for those that didn't get all the way.

9aii Using the 'show that' mass and nano thickness given, candidates now had to find the density of graphene, and compare it to that of graphite (2300 kg $m^{-3}$). Again this was largely well done, by candidates doing a mass / volume calculation, which was pleasing considering the nano thickness, and non-familiar values. Over half showed the density was about 3500 kg $m^{-3}$.

9aii Here candidates had to use breaking stress = Force / cross-sectional area to show an imagined graphene sheet of 0.1 m dimension could support about 1 N force. Most were fine, but weaker candidates often used volume instead of area, and scored zero. Reverse argument solutions are always accepted for full credit, for instance showing here that the stress for a 1 N force was less than the breaking stress.

9bi This was about finding the electrical semi-conductivity of graphene in a direction perpendicular to the layer. Many candidates got one mark for correct evaluation of $G$ (or $R = 1 / G$) but then mixed up the dimensions, or got the wrong cross-sectional area. Only those that kept a tight grip of directions and dimensions and the powers of ten involved went on to get the next two marks by showing the conductivity was $3.8 \times 10^{-7}$ S $m^{-1}$. Each POT power of ten error counted as minus one mark off the possible total of three. Some candidates ignored powers of ten completely here which was unusual, perhaps they were too pushed for time?

9c This part asked for two possible applications of graphene linked to mechanical / electrical properties. The facility was just under a half with a good spread of marks and some imaginative answers and some quite futuristic ones – which gained credit. Others were very vague in choice of application (e.g. buildings or cars – without specifying in which part graphene was used, so gaining no credit). The worst did not discuss any applications at all - or often referred to extra imagined properties (e.g. hardness or slipperiness, lubrication was not accepted as an application), nor those of strength and conductivity developed in the question! Only those that linked the properties to the application could score the QoWC $4^{th}$ mark. There were signs in Q.9 that some candidates were running out of time and rushing.

Q.10 This question was about digital information in the form of a QR code and parts a) and b) were quite well answered. Part c) involved questions about a lens forming an image of a QR code and were probably the hardest marks on the paper. At this stage slower and weaker candidates struggled to score or even attempt an answer.

10a Candidates were asked to suggest and explain an advantage of QR codes over a more traditional bar code. Generally they answered well, but if they got 1/2 marks, it was usually because they missed out that QR codes store more information, rather than the explanation of them having more alternatives, or the 2-dimensional nature of QR codes compared to linear bar codes.

10bi This part asked for a calculation in bytes of the maximum information storable in a 33 x 33 module QR code. Fractional bytes were allowed, so 33 x 33 / 8 = 136.1 was accepted for the mark, but rounding up here to 137 or 140 was a rounding error (RE) scoring zero. Quite a few incorrectly doubled the correct answer quoting 272 bytes which scored zero.

10bii Asked for a statement of the number of alternative characters that can be coded with one byte of information. Over half the candidates could remember that alternatives = $2^{bits}$ and quoted the correct result at $2^8$ or 256 characters. There was a wide range of incorrect answers from 2 to some incredibly large values such as $2^{33 \times 33}$ which generates calculator overflow error (i.e. greater than $10^{99}$).

10biii Asked for a suggested explanation of the three 8 x 8 module squares in 3 corners of the code. All sensible suggestions were credited with a mark and the facility was well over a half which was pleasing. These suggestions included: to recognise the alignment of the QR code, to identify where to start and stop reading the code, to identify it was a QR code, to identify edges / corners / boundaries or help with camera focusing. Error checking was not accepted for the mark.

10ci In part c) the QR code was imaged by a CCD in a digital camera from two different distances. The questions relied on students thinking through the problem rather than a formulaic approach. They needed to grasp that if too close to the QR the image would not fit onto the CCD, and if too far away there would be more than one QR module on each CCD pixel and the pattern would be unresolved. Those that used the concept of magnification( x 5/100) before automatically trying the lens formula were well rewarded, as no hints or structure to the solution were given. They could quickly show, from the dimensions given, that the image height from 100 mm away from the QR was 1.7 mm < the 2 mm of the CCD. Some candidates could not handle magnifications less than 1 (diminutions) and forced an inversion of the $M = v / u$ equation, but realised the image was x 20 *smaller* than the object, this was not penalised. Others tried to redefine an area magnification rather than linear magnification and tended to be inconsistent so gained no credit. Candidates who used the lens formula here tended to produce circular arguments showing that the image was at about 5 mm from the lens which they were given anyway, so this also gained no credit.

10cii Here they had to show that with this close object, the image distance is about 5% longer than $f$ the focal length of the lens. Just over half the candidates attempted this. Very few referred back to ci) if they had done their lens formula calculation there, to show the image was formed at 5.3 mm from the lens. As is usual on lens calculations there was much confusion over object distance $u$ and image distance $v$, or misapplication of the Cartesian sign convention recommended (distances to left of lens are taken negative). Many of the candidates who did attempt this part, sadly ended with a score of zero. A simple single mark could be gained by just calculating a 5% increase on the 5 mm focal length, even if not compared to the image distance. Working in m or in mm was accepted even if not made obvious by the candidates until the final answer was quoted.

10ciii Here there were a few very good answers, if they managed to state clearly that one pixel on the CCD would end up containing the image of more than one QR module, they could secure a mark. So sensible reference to resolution as the problem could score one simple mark of the three. The best went on to show that with an object distance of 2.5 m, the image of one QR module (1mm x 5/2500) was exactly the same size as one CCD pixel 2 x$10^{-3}$ mm, for 2 more marks. However, lots of students had either run out of time or just ended by dividing or multiplying numbers without reference to physics concepts.

# G492 Understanding Processes/Experimentation and Data Handling

**General Comments:**

This is the first examination series for candidates as they did not have the option of a prior January examination for resitting a paper taken previously in June 2013. The numbers were similar to those for June 2013.

Examiners commented on candidates' lack of explanation in questions asking 'Describe and explain' in Sections B and C, although the standard of presentation in terms of laying out both extended writing and calculations seemed better this year. In section C, most candidates showed they were familiar with the advance notice materials but a surprising number showed very poor skill at graphical analysis.

Although examiners reported that they had not seen evidence of candidates running out of time, there was some evidence in the question statistic that the last question had been rushed. Candidates should consider carefully whether to tackle Section C before or after Section B – it is probably worth five minutes at the start of the examination skimming through sections B and C to decide on the best approach.

**Comments on Individual Questions:**

**Section A (Questions 1 to 7)**

This section proved accessible, as intended, with most candidates getting >15/22 and stronger candidates getting nearly all of the marks.
Many candidates had difficulty in estimating the area of cross-section of a finger in Q3(b).
The vector addition in Q6(a) was done well by nearly all as was the use of the diffraction grating equation in Q7(a): in both of these questions, parts (b) were a little more challenging.

**Section B (Questions 8 to 11)**

**Q8 (Tidal energy generation)**
In (a), candidates all used the scale diagram to find an area, but many found the area enclosed by the triangular base, which is of the same order of magnitude as the 'show that' value but is still wrong. Parts (a)(ii) and (b)(i) were well answered but many did not answer (b)(ii) as required: the important statement 'under these conditions' (i.e. with a water velocity of 2.5 m $s^{-1}$) was missed by many. Successful answers suggested mechanisms such as friction between the turbine axles and their mounts, and stated that the 'lost' energy was dissipated as heat.

**Q9 (Photons and electrons)**
In (a)(i), most got both marks, but a number could not convert to pm. In (a)(ii) a surprisingly large number read the 0.50% as either 0.5 or 50% and lost marks needlessly. In (a)(iii) only the best realised that a very considerable power (even at 50% of the input) was likely to damage the X-ray tube.
Part (b), on the wave-like behaviour of electrons, proved harder for many. Better candidates scored well but weaker ones attempted to use $v = f\lambda$ instead of the (given) de Broglie relationship. (b)(iii) was more discriminating, and better candidates gave clear and succinct answers here.

**Q10 (Flute)**
In (a)(i). many candidates could not deduce that the fundamental flute standing wave was ½$\lambda$, and of those that did a small number omitted to convert to m. In (a)(ii) the mark scheme was lenient as the diagram is not easy to draw under examination conditions, but it was notable that some diagrams were very well drawn. The usual 'loopy' standing wave diagram was certainly accepted, even though it strictly applies only to transverse waves, but simply labelling points A and N was sufficient. The explanation in (b)(i) were generally good, and in (b)(ii) most candidates gained some credit but only the best were able to gain all 3 marks: the point usually missed was to explain that $\lambda$ is constant, so $v \propto f$.

**Q11 (Diver)**
In (a), many gained a mark for stating that $F \propto a$, but few related $a$ to the gradient at the very start, rather than over the interval AB. In (c)(i) many failed to specify what displacement was given by the area: either 'during the interval BC' or 'from the board to the highest point' was needed. In part (d), one of the lowest-scoring parts of the paper, many concentrated on what happened at D rather than between D and E.

**Section C (Questions 12 to 14)**

As mentioned in the general comments, candidates often did not explain where the question stated 'explain'. It is important for candidates to look carefully at the command works in the question, so that they can answer what was set rather than what they thought it ought to have been. This is particularly important in this section as centres spend some time preparing candidates for potential questions, and it is tempting to fall back on what they have practised.

**Q12 (Oscilloscopes)**
Parts (a) and (b) were well done by most, but parts (c) and (d) were not. This is because 'explain' is not 'quote a bit of the article'; in (c) it was necessary to identify an advantage or disadvantage and explain it for each mark; (d) was less stringent, with one mark of each pair given for quoting a necessary advance in technology, with the second mark for explanation. In (d) a number wanted to write about analogue to digital conversion, or LCD screens, but neither were relevant here.

**Q13 (Powering electric cars)**
Parts (a)(i) and (ii) were well done by most, few gained 3/3 in the latter due to lack of clear physical reasoning for a large mass being a disadvantage of a car, although most realised a fork-lift truck is less likely to topple over if it is massive with a low centre of mass. In (b)(ii) many used $P = Fv$ to calculate the mean power, which is acceptable only if the mean velocity is used. In (b)(iii), most calculated the discharge time as 1½ hours but it was then a lottery as to whether to calculate 16 kWh/1½ h or 16 kWh × 1½ h; including units in the calculations (quantity calculus) would help to prevent this sort of error.

**Q14 (Simple pendulum experiment)**
In (a)(i) some failed to link to human reaction time, and of many that did some answered (a)(iii) (why is the uncertainty per period in measuring 10 oscillations 0.01 s?) 'because that's the resolution of the stopwatch.' (a)(iv) proved very taxing: a small number calculated one or both extreme values of $T^2$ to find the difference from 1.21 s$^2$, which was what was expected. A smaller number adopted this alternative, quite correct, approach: as $T$ is squared, the percentage error in $T^2$ is twice the percentage error in $T$. A very great number quoted 'as $T$ is squared, you double the uncertainty' which is incorrect: it happens here to give a similar result as $T$ is not very different from 1.

Possibly due to rushing, the results to part (b) were disappointing. Nearly all could complete the table, but about one candidate in four failed to plot the two points. Explaining why the gradient of the graph is $\frac{4\pi^2}{g}$ was done well by most, and the graph was usually well done, with a few losing marks for not drawing a best-fit line, for using too small a gradient triangle, for calculating the gradient using points in the data table which were not on the line, or for quoting $g$ to four or more significant figures. Cannier candidates spotted that a line from (0,0) to (0.4, 1.6) was a pretty good fit and made the calculation very straightforward. In (c) most got the idea of reduced percentage uncertainty for time and/or length and most discussed the practicality of setting up and using such a long pendulum, but not always successfully.

# G493 Physics in practice

### General comments

The moderation process for the vast majority of centres was straightforward this year as the overall quality of administration was high. Following the request for the sample most centres responded promptly in submitting well-organised portfolios together with the associated documentation. However, the use of plastic wallets and cardboard folders is not recommended as this can provide unnecessary work for moderators; it is sufficient for candidate's work to be securely fastened together. The thorough checking of the addition and transcription of marks prior to submission was appreciated and there were few clerical errors. However, whilst evidence of internal standardisation is welcome, the inclusion of more than one Coursework Assessment Form can be confusing and the agreed definitive mark must be clearly indicated.

It is expected that the work of candidates should be annotated to show where marks have been awarded as this enables the moderator to easily check that the assessment criteria have been applied correctly. It is particularly useful to the moderator when teachers indicate errors of physics or mathematics. Although the level of annotation for the Quality of Measurement task was generally high, there tended to be fewer comments to support the marking of the Physics in Use task.

Many centres were allocated the same moderator as in 2013 and some had clearly acted on the specific feedback given in their individual reports last year. However, in other cases moderators reported similar discrepancies relating to the awarding of marks to those noted previously. Common issues for each of the two tasks are summarised below.

### Quality of Measurement task

The vast majority of experiments chosen for this task were appropriate and covered a good range of physics from the course. Some interesting variations on the standard resistivity/conductivity experiments were seen where carbon putty or graphite was investigated rather than the more usual constantan or nichrome wire. Experiments to measure '*g*' were a popular choice, but it is not intended that methods based on timing the period of oscillation of a pendulum are undertaken as the theory lies outside the AS level specification. Guidance on suitable methods for measuring '*g*' is provided in the activities section of chapter 9 of the Advancing Physics CD-ROM. The properties of lenses (chapter 1), sensors (chapter 2), materials (chapter 4) and waves (chapter 6) are other fruitful areas of the AS course. Giving candidates the opportunity to choose from a range of possible experiments also provides a better preparation for the Practical Investigation component of the A2 course.

In strand A '*Quality of practical work in the laboratory*' candidates are required to provide written evidence that they have addressed relevant safety issues to satisfy the descriptor dealing with '*careful methodical work*'. This was sometimes lacking, even in cases where there were clear potential hazards with the experiment. A short risk assessment (which may find no substantial risks) is a simple solution.

In general, candidates are now demonstrating a greater understanding of uncertainties and systematic errors in strand B. However, some candidates tended to focus solely on the resolution of the measuring instruments used, rather than considering the (often larger) range of repeated measurements. There are a number of experiments on the CD which may help to develop an appreciation of this aspect of uncertainty at an early stage of the course. For example, ideas of '*Plot and look'* can be introduced through Activity 110E: '*Using a digital multimeter to measure resistance*' in Chapter 2 or Activity 100E: '*Measuring breaking stress of materials*' in chapter 4. A common shortcoming in strand B was the lack of an appropriate evaluation of the effect that any suggested improvements to the experimental method had made to its outcome. This idea of progression in experimental work can be addressed through, for example, Activities 250E-253E '*Measuring wavelength better and better*' in Chapter 6.

In strand C '*Quality of communication of physics in the report*' errors in the recording and presentation of data such as missing/incorrect units or the inconsistent/ inappropriate use of significant figures in tables of results were sometimes overlooked by the centre assessor. A few candidates embarked on potentially interesting projects that did not lend themselves to drawing graphs. In such cases teachers should offer advice, directing the candidate down a more appropriate path in order give them greater opportunities to meet the assessment criteria. Candidates should be penalised for graphical plots which lack clear labels, uncertainty bars or appropriate best fit lines. In general, candidates electing to produce computer-generated graphs using Excel were less successful than those who drew them by hand. A common fault was in the choice of a 'line' graph, rather than the more appropriate 'scatter' one. Although primarily assessed here the relevant physics should be integrated into the report, rather than being dealt with in a separate 'theory' section near the start, or tacked on at the end.

In strand D '*Quality of handling and analysis of data*' candidates often placed too much reliance on tabulated data. Information should be extracted from the gradients, intercepts or other features of graphs for high marks to be awarded. However, the use of the Excel function that gives the equation of the best fit line led some candidates to propose purely mathematical relationships, rather than ones based on a knowledge and understanding of physics. Final values of measured quantities should be qualified with reference to uncertainties and possible systematic errors; for example the gradient of a graph might have +/- values associated with it.

**Physics in Use task**

The vast majority of candidates now use PowerPoint as their chosen medium for the Physics in Use presentation. However, it was difficult to judge the quality of the work produced in some cases as the printout of the slides was too small to read easily. Candidates must produce a clear record of their presentation to be awarded high marks in strand A(iii). There also tended to be less teacher annotation for this task, either on the Coursework Assessment Forms or on the work itself, and this made the moderation process more difficult. Teachers can assist the moderator by commenting on the oral aspects of the presentation, for example by indicating whether the candidate was able to expand on the information presented on the slides. The quality of candidate responses under questioning may also be recorded. Printouts of slides should be annotated to highlight aspects of both good and poor physics; otherwise the moderator may assume that any errors not noted have been overlooked when awarding marks.

In strand A(i) some candidates did not appreciate the requirement to place their chosen material in a clear context, tending to list its general properties rather than those related to a specific use. A clear context for the material also enables candidates to focus on the relevant macroscopic and microscopic properties in strands B(ii) and B(iii). It can be helpful to couch the title as a question, such as "Why is carbon fibre used for fishing rods?" as this immediately focuses the candidate on the properties needed for that application. Other interesting topics chosen this year included:-

- Aluminium in power lines
- Balsa wood for aircraft
- Bamboo in skis
- Carbon nanotubes in heart scaffolding
- Graphene in smartphones
- Inconel in oil and gas subsea mining
- Lead in fishing weights

- Leather in basketballs
- Magnesium alloys in steering wheel armatures
- Nickel super-alloys in jet engines
- Sapphire glass in smartphones
- Shear-thickening fluid in liquid body armour
- Silica gel in space suits
- Titanium for jet engine fans
- Vectran in the strings of tennis rackets

The use of '*Sources*' in strand A(ii) of the assessment criteria continues to improve. Here most candidates are now identifying the information used more clearly by, for example, quoting the full web address for internet-based sources. There were also improvements in the subsequent linking of the information sources to the presentation itself, often achieved by simply linking the name of the source to the slide number concerned. However, print-outs of the source material itself should not be sent to the moderator. It is preferable to provide the bibliography as a separate Word document rather than as the final slide of a PowerPoint presentation, as the resulting small text can then be particularly difficult to read.

# G494 Rise and Fall of the Clockwork Universe

### General Comments

It was good to see that candidates are better at combining formulae from the data booklet to calculate a quantity, although weak candidates are no better at following the contextual thread through a Section B question. This paper always contains many questions which require candidates to explain things; as ever, weak candidates still lose many marks by failing to write precisely enough, omitting important details in their account.

### Comments on Individual Questions:

### Section A

As ever, this section contains short questions covering the whole module specification. Most of them were straightforward, some were less so to provide some discrimination overall.

1 This was the usual units question to start off the paper. Very few candidates were unable to identify the correct SI unit for momentum. The equivalent unit for pressure proved to be more difficult, with many weak candidates clearly guessing instead of trying to work it out.

2 Although the majority of candidates were able to correctly sketch the V-Q graph for a capacitor, only a minority of even the most able candidates were able to sketch the correct E-Q graph; many candidates wrote down the formula E = QV/2 and decided that E had to be proportional to Q.

3 This question was about resonance in mass-spring systems. Many candidates lost the mark for part **a** by not being precise enough about what it was that was oscillating - the mass or the support. Most candidates were able to explain the effect of damping.

4 The vast majority of candidates earned full marks for their calculation of the speed of a molecule. This is impressive since they have to combine two separate formulae from the data sheet to obtain the answer.

5 It was good to see that most candidates were able to use the data provided to show that momentum was conserved in the collision.

6 The vast majority of candidates were able to correctly identify the V-T graph for an ideal gas.

7 Although most candidates knew that random walks were the result of collisions between molecules, only a minority made it clear that it was the results of those collisions that was random. Most candidates tried to fit the data provided to a square root rule without justification; only the strongest candidates started from the root-N rule for particle displacement.

8 Most candidates were able to use the Hubble law for this calculation as well as state the assumption behind it.

### Section B

This section consists of four questions, each set in a context from a different part of the module specification.

9 This question was about the motion of an asteroid in the Sun's gravitational field. It was good to find that the vast majority of candidates were able to select and correctly combine two formulae from the data sheet to prove the required expression for the speed of the asteroid in a circular orbit. Most candidates were then able to use the expression to calculate its kinetic energy; weak candidates often tried to start from scratch and calculate the gravitational energy as a first step. The next part of the question was stretch-and-challenge, designed to be inaccessible to weak candidates, and so it proved. Only the strongest candidates understood what to do. The commonest error was for candidates to use the circular-orbit formula to calculate the kinetic energy, not realising that it couldn't apply to an elliptical orbit. The final part of the question required candidates to explain how remote distance measurements are made; many lost marks by not being precise about the nature of the radiation being used (radar on its own earned no credit) or the definition of t in their formula $d = ct/2$.

10 This question was about using the Boltzmann factor to model the evaporation of water. Calculation of the energy required to raise the temperature of the water caused most candidates little difficulty, although too many neglected to state the assumption or provided incorrect ones (such as heating the water evenly). Similarly, the vast majority of candidates correctly calculated the evaporation energy per molecule from the data provided. It was good to find that the majority of candidates were able to explain the meaning of the Boltzmann factor correctly, although few candidates related it to the continual exchange of energy between molecules through collisions. The last part of the question was another stretch-and-challenge calculation, this time involving an exponential. As expected, weak candidates got nowhere with it and most strong candidates got it out correctly.

11 Although many candidates understood how to apply the correction for background radiation, too many were not very clear about how background radiation could be measured in the first place. Most were unable to convincingly combine the two given formulae to generate the required expression for lnA; only a minority appreciated that the activity had to be -DN/Dt, so most candidates ended up trying to take the logarithm of a negative quantity. The calculation of half -life from the data in the graph proved to be much more difficult than expected. Many candidates ignored the expression that they had just proved and tried other methods, usually to no avail. A majority of strong candidates realised that they needed to use the graph to obtain a value for the decay constant which could then be used to calculate a half-life; too many failed to notice that the horizontal axis was in minutes, not seconds. About half of the candidates realised that the random nature of radioactive decay meant that real data didn't have to exactly match values calculated from the model.

12 This question was about the assumptions behind the derivation of the ideal gas law PV = NkT. About half of the candidates failed to explain that the model assumed elastic collisions between the particles and the container walls, and only a small minority convincingly explained why each particle travelled twice the length of the box between collisions. Although most strong candidates were able to correctly justify the factor of N/3 when considering all of the particles in the box, too many candidates invoked the six faces of the box or the formula $p = r\, c^2/3$ rather than the three different dimensions in our universe. For the final part of the question, candidates had to explain how one equation could be made to look like the ideal gas law; the majority simply used algebra, with no words of explanation, earning little credit. Only the strongest of candidates mentioned the assumptions about relating average kinetic energy to temperature and show how they led to the final expression.

# G495 Field and Particle Pictures

**General Comments:**

The marks on this paper ranged from 4 out of 100 up to 98 out of 100. The mean of 61% is similar to recent sessions. There was very little evidence of candidates running out of time and few questions were left blank.

The spread of the responses showed that candidates had been well prepared for all areas covered in the examination and the better candidates were able to use physics in novel contexts with confidence. Once again, Centres had prepared candidates for the questions based on the advanced notice article with care.

Some of the work was on the edge of legibility and some candidates lost marks in 'show that' questions through lack of clarity of their arguments. As always, this was particularly noticeable when manipulating units.

More care was shown with significant figures in this session, but candidates still lose marks through rounding errors. As in previous sessions, the better candidates pick up marks on calculations whilst the best gain marks on calculations and explanations.

The paper was of a similar degree of difficulty to previous years and as the mean mark is similar to recent sessions it would appear that candidates for this paper have not been adversely affected by the removal of the January session and the increase in the number of examinations taken by candidates in June.

**Comments on Individual Questions:**

**Section A**

Question No. 1
This is a straightforward opening to the paper. The only problem here was recognising that the unit of force can be written as $Jm^{-1}$.

Question No. 2
This easy recall question was correctly answered by the majority of the candidates.

Question No. 3
Part (a) proved a more challenging task. Many candidates wrote of the particles travelling in opposite directions (which they do not do for the majority of the track) and weaker responses incorrectly suggested that the positron and electron repelled each other. This will be a useful question to discuss in class to show the importance of choosing words carefully.
Part (b) was answered with more confidence with most candidates recognising the link between the magnitude of the momentum of the particle and the curvature in the magnetic field.
Part (c) was a simple calculation that was clearly answered by the majority. (Answer: $1.2 \times 10^{-12}$ N)

Question No. 4
Part (a) was very poorly answered. This shows that candidates are able to gain marks from mechanical calculations (as they did in part (b)) without having a clear idea of the physics of the situation. Electromagnetism questions always prove challenging but it was surprising how few candidates could recall that the flux in an ideal transformer is considered to be constant throughout the core.

Part (b) Nearly all candidates scored both marks here and reached acceptable answers of 520 (2sf), 521 or 522.

Question No. 5
This was one of the most accessible questions on the paper. The most common error was to circle the bottom of the slope (that is, the point of most negative binding energy), but only very few candidates failed to gain the mark.

Question No. 6
An explanatory question on electromagnetism in Section A of the paper is a departure from the norm but about half the candidates gained two or three marks.
The majority of candidates scored the mark for considering a flux change in the copper. The better responses described the induced emf driving current that sets up a field. The mark scheme allowed a number of ways to gain marks but did not allow a bald statement of Lenz's Law, and those candidates who did state the relationship often failed to gain marks due to confused explanations. For example, many candidates incorrectly suggested that the emf created the magnetic field or that the emf opposed the motion of the iron rod.

Question No. 7
This question was answered correctly by most candidates, gaining the correct value of $2.1 \times 10^{-13}$ m through a direct rearrangement of the equation given, or by working through to an intermediate value of momentum ($3.09 \times 10^{-21}$ kg m s$^{-1}$)

Question No. 8
This proved a little more challenging with weaker candidates choosing the value 2 rather 4.

**Section B**

Question No. 9
This question was about Rutherford scattering and used results from the original 1913 paper.
9a. Only the very best candidates gained four marks. About half the responses gained the two easiest marks, that number of scattered particles per unit time decreases with increasing angle and that gold generally scatters more particles than silver.
Few candidates commented on the dramatic difference in number of particles scattered as the angle changes. This may show that they did not look at the y-axis values with sufficient care. Responses often included theoretical justification for the results even though this was not asked for. It is clear that candidates were well-versed in the scattering experiment but, perhaps in a rush to write down what they knew, they moved away from the point of the question.
9b. Continuing in the manner of recent papers, the arithmetical part of the question, giving a value of $3.8 \times 10^{-14}$ m was answered with much more confidence than the descriptive parts.
9ci. The explanation of nuclear density being independent of the number of nucleons was rather poor from the middle and lower-ranked candidates, many of whom produced circular arguments of little worth.
9cii.Once again, notwithstanding a poor performance in (c)(i), most candidates gained the marks for the calculation (answer: 1.9(4)).The comparison is stark: over 70% of the candidates failed to score on c(i) whilst over 80% gained full marks for part (ii). This simply shows that explaining points of physics has a very high-level demand.

Question No. 10
This question was about beta decay. It was the most accessible of the Section B questions.
10a. This asked for two conserved quantities. 'lepton number' and 'charge' were the most popular correct choices. Some candidates incorrectly suggested that 'energy' or 'mass' were conserved.
10b (i).This standard calculation leading to a value of $1.3 \times 10^{-13}$ m caused very few problems.

10 b(ii). This part was rather more discriminating. Many candidates gave circular answers of the form ‘because protons are stable particles’. This is a useful lesson in examination technique: part (ii) will refer to part (i).
10c (i) Unit manipulation is always problematic for the medium and lower-ranked candidates. Although marks could be gained through a very simple method many candidates did not complete the derivation clearly enough to gain both marks.
10 c(ii) Once again, a straightforward calculation. Most candidates achieved the correct value of $3.6 \times 10^{-36}$ kg.

Question No. 11
This question, about a simple generator, was more discriminating and, as although the context will have been familiar to many, the form of questions took a little thinking about.
10 (a) Part (a) required candidates to calculate the length of the side of the square coil. This was challenging as the candidates had to take a value for maximum flux linkage from the graph, realise that this occurs when the coil has maximum effective area, calculate the cross sectional area and then square root the value. Nearly all the candidates who evaluated the cross sectional area gained both marks, reaching the value 0.06 m.
10 (b) This part revealed lack of mathematical knowledge in some candidates and rather hurried reading of the question leading to contradictory answers. This will be another useful question to discuss in class. The first method required finding the maximum gradient of the graph line( giving a value between 16 and 18 V). Most candidates attempted this and gained some credit. Assuming that the time axis was in seconds was a common error. The second method required the use of an equation that was given to the candidates. Many candidates assumed that the emf would be the greatest when the flux linkage was the greatest (rate of change = zero) even though they had used the maximum rate of change of flux linkage in the previous part of the question. This gave some candidates an emf value of zero whilst others assumed the angle was in degrees and so reached an incorrect, non-zero value. The presence of $2\pi$ in the sine was a sufficient memory jog for the better candidates to work in radian, and the most mathematically confident recognised the maximum value of sine is 1.
The final part of the question required candidates to compare methods of obtaining the emf. Many recognised the difficulty of establishing a gradient with confidence but only the very best compared this to the uncertainty in the data used in the second method.

Question No. 12
The last question in section B was about Bertozzi’s demonstration of the relativistic effects on accelerated particles.
(a) About a quarter of the candidates drew field lines with the arrows towards the positive plate. Others lost marks through poor drawing, non-uniform fields and field lines not ending at the plates. The best responses showed that great care had been taken.
(b) The second part of the question asked candidates to calculate the kinetic energy of the accelerated particles and use the value to calculate velocity, ignoring relativistic effects. These calculations were performed correctly by the vast majority.
(c) Similarly, this part was a very easy calculation of velocity giving the result of $4.2 \times 10^{8}$ m $s^{-1}$.
(d) (i) This part of the question required candidates to calculate the rest energy of an electron and from this the gamma factor of the accelerated particle. This was more challenging to the weaker candidates. Some just divided kinetic energy by rest energy, others attempted to calculate the gamma factor through another method and could not gain the mark for calculating the rest energy of the electron.
(d) (ii) This was more challenging again. Only the top 40% gained both marks, reaching a value of $2.6 \times 10^{8}$m $s^{-1}$. Many came unstuck in attempting to rearrange the gamma factor equation and missed a relatively easy mark (no pun intended) for substituting the gamma factor correctly into the equation.
d(iii) The comments on the value obtained in d(ii) were often too broad to gain credit ‘less than the speed of light’ was a common response.

(e) Most candidates gained at least one mark by stating that protons are more massive than electrons. The second mark, explaining the consequence of this greater mass, was harder to gain.

**Section C**

These questions were based on the Advance Notice article. It is clear that many Centres prepared candidates for this section with care. There was little, if any, evidence that suggested that candidates were growing fatigued at this stage of the paper as the proportion of unanswered questions in this section was no greater than in Section B.

Question No. 13
This question asked candidates to identify and explain advantages of LiF chips over photographic film. Many candidates gained marks for correctly identifying advantages as required, but some veered into discussions of material properties that did not address the ease of monitoring dose. Many candidates missed a mark through stating that the chips can be reused whilst omitting to provide an explanation for this property; others mistakenly suggested that this property is a consequence of the natural fading of electrons to the ground state.

Question No. 14
(a) Most candidates correctly identified the importance of the quality factor in the dose equivalent and gave answers that showed greater understanding than merely quoting the relevant equation. Fewer gained the second mark, although many made reasonable but insufficient statements. For example, candidates rarely considered the different effects on tissue – just stating that different radiations are 'more damaging'.
(b) This multi-stage calculation was performed well by many candidates with about 70% scoring all four marks, reaching the answer $6.3 \times 10^{-3}$ Sv. The most common error was multiplying the absorbed energy by the mass.

Question No. 15
This question was about the mechanical properties of LiF. Most candidates identified the crystal as brittle and correctly recalled a consequence of this property to gain the first mark. The majority of candidates correctly described the ionic lattice structure or the directional bonds within the crystal to gain the second mark. The third mark proved less accessible.

Question No. 16
This question consisted of three calculations. Nearly half the candidates gained all ten marks here and showed confidence and clarity in their working.
(a) Nearly all candidates gained four marks for this part.(final answer = $5.4 \times 10^{17}$ ).
(b) This part, requiring candidates to show the energy of a transition to be about 4 eV, was more challenging with the lower fifth of the candidates gaining no marks. The working of the weaker candidates showed rather random calculations which sometimes reached a reasonable-looking value but gained no credit. The better answers showed that the candidate had considered the question before putting pen to paper. There is a lot of information in the stem of the question which needs a little thought to marshal into a data set that can be worked with.
(c) This was a straightforward question and the majority reached the correct value of $3.3 \times 10^{-7}$ m. Some candidates who made obvious errors in part (b) carried these into part (c) rather than using the 'show that' value. This is not good practice.

Question No. 17
This rather novel question was answered well by many, but showed good discrimination with candidates scoring across the range of marks. About one-third of the answers gained full marks. The poorest answers did not address the question, putting the symbols into words rather than explaining the steps that lead from one line to the next. Medium-ranked candidates lost marks for imprecise statements such as 'take the (natural) log of 0.95' rather than 'take natural logs of both sides'.

Question No. 18
This question was about the photomultiplier tube.
This part required a statement of the assumptions made in using the equation $eV = \frac{1}{2} mv^2$. This proved to be a challenging question, with only about one in ten candidates gaining both marks. Common errors included suggesting that 'air resistance' had to be ignored rather than considering collisions at the scale of particles. Candidates often gave the same suggestion twice; for example, stating that relativistic effects are not important and then stating that the mass of the electron doesn't change. Some candidates made statements that showed a lack of understanding of the situation; for example, stating that an assumption is that the electrons do not change their velocity.
(b) This part of the question was aimed at higher-ranked candidates and was challenging to many. The most common incomplete response was to consider that the electrons 'shared' energy as the number multiply at each stage without explaining that all electrons are emitted with approximately the same value of kinetic energy and pass through the same p.d between each pair of dynodes.

Question No. 19
(a) This simple 'show that' question proved accessible to all but the weakest candidates.
(b) The last question on the paper was of a higher demand and it was encouraging to see that over half the candidates gained all three marks for reaching the correct answer of between 51 and 53 electrons incident on the first dynode. (The range covers the various values used for the number incident on the anode.)

# G496 Researching physics (A2)

### General Comments

Moderators reported that most Centres are now very familiar with the requirements of the specification for favourable assessment in this practical component of the Advancing Physics course. Administrative mistakes such as arithmetical and transcription errors, the lack of an obvious internal moderation procedure and the late arrival of the moderation sample remain minor but time consuming issues for Coursework moderators. Clerical errors trigger a complex chain of events for centres and moderators alike which is easily avoided if a careful check of marks is undertaken at source. For centres where substantial downward adjustments were made to the marks, these were nearly always cases where there was a significant mismatch between the marks awarded and the depth and quality of the physics included. As an 'A' level assessment it is imperative that students demonstrate that they have a good grasp of the A2 physics underpinning their chosen titles.

### Practical Investigation

Moderators reported that where coursework portfolios were deemed generously assessed the root of the problem was nearly always with the Practical Investigation. Strand A (Independence) should not be scored highly simply because the student did not ask many questions. Some centres continue to allow several students to investigate the same topic which is a practice that should, wherever possible, be discouraged. One centre of 15 students submitted 5 Investigations involving Newton's Law of Cooling. With a completely open choice of topic for candidates there is no excuse for this level of replication.

There was also evidence that the scope of some of the Investigations tackled was far too limited. Examples of these were; bounce height for balls where no temperature change was involved, measurement of magnetic field around a coil where no changes were made to the coil or the current flowing through it. Standard course experiments can be extended to make them into appropriate investigation topics but must not be a closed exercise where few if any of the outcomes are a surprise to the candidate. The inclusion of every result recorded by a data logger sometimes resulted in overly inflated reports. The moderator will only want to see a representative sample of such data, not all 300 pages and candidates should not include it all, even in an appendix! Candidates seem too quick to resort to data loggers and video capture techniques e.g Tracker, rather than exploring simpler, more traditional methods, at least at the outset. The report produced should stand on its own merits, be concise, coherent and completely focused on the need to describe what was done, how it was done and what might be concluded from the evidence assembled.

It is essential that Practical Investigation reports that are awarded high marks should show a degree of development guided by the understanding of the underlying physics. It will help if the title framed at the outset is offered in the form of a question e.g 'How does the Bounce Height of a Squash Ball depend on its temperature?', 'How does the strength of the magnetic field of a solenoid vary with current?' Too many reports were scored highly despite having demonstrated very little development.

It is expected that the skills learnt during AS coursework are secure at A2, so an appreciation of the uncertainty in data, on graphs and with the instruments being used to make the measurements should be recorded. Tables need headings and graphs need major and minor gridlines, titles and sensible best fit lines.

**Research Briefing**

The need to write in continuous prose and use diagrams and pictures to relate their research on a topic of their choosing seems to be well understood and popular with students in this cohort. Some centres remain uncertain about how they should record the questioning process which must take place in support of Strand B (Understanding). The best centres include the notes which were taken during the short interview to assess this component of the work, some let their candidates run the gauntlet of peer group questioning to ascertain the level of understanding of their charges. One criticism often levelled by moderators is that too many students are able to submit Research Briefings with virtually no physics content. This is best avoided by vetting the titles quite vigorously and asking some probing questions, what physics from the course does that include and what chapter would that involve from the course?

Coursework is both time consuming and demanding for teachers and students. The best candidates continue to research some genuinely novel topics and carry out intriguing investigations, revealing a genuine passion for their work. Centres continue to extract high quality work from their candidates. The true spirit of investigation remains alive in Advancing Physics Centres across the country.

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