PHYSICS

Paper 9792/01
Paper 1 Multiple Choice

Question Number	Key	Question Number	Key	Question Number	Key	Question Number	Key
1	A	11	D	21	A	31	A
2	A	12	B	22	C	32	C
3	C	13	A	23	D	33	C
4	D	14	B	24	C	34	A
5	D	15	D	25	A	35	C
6	B	16	C	26	D	36	C
7	A	17	B	27	B	37	D
8	C	18	B	28	D	38	B
9	D	19	C	29	B	39	D
10	A	20	B	30	B	40	C

Candidates again appeared to have been prepared well and have a good understanding of all parts of the syllabus. Section A had seven questions which candidates found straightforward whereas section B had three. The most difficult questions this year on the whole paper were **Question 27** and **Question 32** appeared to be the most difficult.

All questions showed a positive discrimination. More able candidates tend to perform well across the syllabus topics, weaker candidates tend to find the section B topics more difficult. A few candidates scored full marks.

Lower scoring candidates tended to find questions with trigonometrical relationships more difficult.

On part A of the syllabus, **Questions 2, 3**, **6**, **11**, **12**, **13** and **20** appeared to be straightforward.

On part A of the syllabus, low scoring candidates found **Questions 5**, **10**, **14**, **16**, **18** and **19** to be challenging.

In **Question 1**, low scoring candidates selected **C** – presumably confused by the length term.

In **Question 5**, low scoring candidates often omitted to add on the 5.0 cm.

In **Question 10**, low scoring candidates often used the inverse tan ratio to gain answer **C**.

In **Question 14**, low scoring candidates often chose **D** for using cos 30.

In **Question 15**, the common distractors chosen by low scoring candidates were **B** (using the first order and the distance of 3.6 cm) or **C** (using either the first order or 3.6 cm).

For **Question 16,** many candidates were confused by leading and lagging.

In **Question 17** many candidates did not read the question carefully and gave the answer **D**.

In **Question 18**, candidates needed to determine that 20 counts per second allowing for background count equated to 6 counts per second and therefore four half-lives. Thus, five minutes is two half-lives.

In **Question 19** many candidates did not realise that the de Broglie wavelength was inversely proportional to the square root of *E*.

On part B of the syllabus, **Questions 24**, **34** and **38** were well answered.

On part B of the syllabus, low scoring candidates found **Questions 26**, **27**, **29**, **32** and **39** to be challenging.

In **Question 26**, low scoring candidates often gave **B** as the answer – not using the distance to point P.

In **Question 27**, the common incorrect answer was **C**, while in **Question 29**, **A** and **C** were often incorrectly selected.

In **Question 32**, a significant number of candidates selected either **A** or **B** (incorrect trigonometric relationship.

In **Question 39,** low scoring candidates found this question challenging with all of the options available being chosen.

PHYSICS

Paper 9792/02
Paper 2 Written Paper

Key messages

- Many of the responses were of a very high standard.
- Questions requiring a numerical response were well answered. Other questions requiring a more extended written response presented a challenge for many candidates. This was reflected in answers that needed a greater degree of focus on the question that was asked.
- Handwriting and the sequence of steps in calculations were not always clear. Consequently, a candidate who had not scored full marks for a question might not achieve credit for work done in that question because the working was not clear.
- Marking many of the scripts was a pleasure.

General comments

- It was a pleasure to mark so many scripts of such a high standard. Most candidates scored over 60 per cent and more than a quarter scored over 80 per cent. No candidate scored 100 per cent.
- The responses show much evidence of excellent teaching and learning. The less successful responses indicated a need for candidates to show a greater focus on the question and give greater clarity in the logical presentation of their responses.
- Answers to questions requiring a numerical response were, for the most part, well done.

Comments on specific questions

Section 1

Question 1

This question was well answered.

(a) (i) Well answered; Candidates showed a good understanding of representing a vector as to perpendicular components.

(ii) Almost all scored full marks. Most used the equation $v = u + at$, with $v = 0$ at the highest point, to determine the time. A very few attempted to answer using other 'suvat' equations to calculate the distance and use this to determine the time.

(b) (i) Well answered with most candidates using cos θ to determine the horizontal component of the initial velocity.

(ii) There were many good responses scoring the 4 marks that were available. Other responses attempted to use appropriate 'suvat' equations but with incorrect numbers inserted. These included calculating the time for the projectile to fall from the cliff assuming a starting velocity of zero or calculating a time using $s = ut + \frac{1}{2}at^2$ with incorrect signs in the equation.

(c) This produced a range of responses; mostly good. A good understanding of projectiles allowed candidates to state that the time to reach the highest point would be less and the horizontal distance travelled would be less. In some responses the reasons for the statements were not clear. There were some ambiguous phrases such as: 'more quickly getting slower'.

Question 2

Mostly well answered although the calculation did present a difficulty for some.

(a) There were some very accurate responses showing a clear understanding of the difference between weight and gravitational field strength. Some did not state the weight was a force or gave an explanation in terms of an equation for the weight as equal to $m \times g$. This did not give a full response to the question.

(b) The responses suggested that field lines and their direction were well understood. Only a few candidates drew lines parallel to the surface of the Moon or drew unequally spaced field lines.

(c) There were some excellent responses showing a good understanding of force and acceleration. A small number of candidates incorrectly used the thrust of the rocket as a resultant force rather than recognising that: resultant force = (thrust of a rocket – the weight of the rocket.)

Question 3

Most candidates demonstrated a sound understanding of elastic and plastic deformation.

(a) Mostly well answered with candidates gaining the mark. Some did not gain the mark because whilst what they had written was correct, it did not answer the question. For example, 'When force removed from rubber band it does not return to its original shape'. This was true but it did not relate to the question on the use of the term elastic. Others did not gain the mark because of a seeming lack of understanding about the word 'elastic'. For example, 'It is not a straight-line graph, so it is not elastic' or 'Not kept proportionality (thus not elastic)'; 'Does not obey Hooke's law (thus not elastic)'; 'not correct elastic is a property of a metal. Elastic does not mean rubber', and these were all responses that did not gain the mark.

(b) Well answered; most appreciated that the spring constant k was the slope of the graph. Whilst a significant number did use the initial straight-line proportion of the graph to determine a value for k many others used a different section of the graph giving an incorrect value of k.

(c) Most candidates appreciated that the work done could be determined by finding the area under the line on the graph. What many found more challenging was to determine the actual value of the work done in stretching the rubber band.

(d) Most were able to gain the mark for explaining that the region represented the increase in internal energy in the elastic band.
Very few stated that this area represented: (the work done in stretching – the energy released in relaxation).

Question 4

Most answers to this question demonstrated a very sound understanding of forces, acceleration, velocity and the relationship to power. The 'show that' aspects of the question were not always well answered. Using data to justify, or not, the maximum range of a car as 270 km presented difficulties for many candidates.

(a) An excellent set of answers with almost every candidate gaining full marks. Calculations using $a = (v - u)/t$ and $F = ma$ seemed to cause little difficulty. Some candidates did not appreciate that in a 'show that' question it was necessary to 'show' where the numbers come from rather than giving a set of numbers and numerical equations.

(b) Almost every response indicated a good understanding of the relationship between force power and velocity. The calculation for mph into $m\,s^{-1}$ was well done. Many candidates did not score full marks because the question was not answered in terms of 'Show that'. The relationship $F = P/v$ or equivalent needed to be included.

(c) This was the least well answered part of the question. There were a few different ways to answer the question any of which could achieve full marks. Many candidates did not include the efficiency in calculating energy that could be delivered through the motor and calculated 1.98×10^8 J incorrectly rather than the correct 1.78 × 10^8 J. The distance 270 km featured in many responses followed by calculations including a number for the distance travelled or the driving force required for a range of 270 km. It was not always clear how the candidate then used this to determine whether the claim was valid. It was necessary for a response to include a clear statement as to why the claim was or was not valid for the candidate to gain full marks.

Question 5

A good set of answers with most candidates demonstrating a sound understanding of current and e.m.f. in parallel electric circuits.

(a) (i) An excellent set of responses; most candidates correctly selected the appropriate loop of the circuit to determine the current in the 18 Ω resistor and thence, via Kirchhoff first law, the current in the battery.

(ii) An excellent set of answers with candidates demonstrating a good understanding of the meaning of the relationship between charge and electric current.

(b) There were a mixed set of answers. The application of Kirchhoff II was correctly applied round the outer loop or around the right-hand side loop of the circuit by many candidates. Others attempted to determine the internal resistance r, incorrectly, using an equation of the form $E = I(R + r)$, followed by $4.5 = 0.84(18 + r)$.

(c) Most candidates were able to appreciate that reducing the internal resistance caused the electric current to increase and that the battery X would charge more rapidly.

Question 6

This was another well answered question with a significant number of candidates scoring full marks.

(a) An excellent set of responses with candidates using data from the diagram to calculate accurately the refractive index of Perspex™.

(b) This presented more of a challenge for a few candidates. An equation using the angles of refraction and incidence between Perspex™ and glass tor the refractive index of glass was incorrectly used. Several candidates gave an incorrect number of significant figures with the answer. 3 significant figures were required to match the data.

(c) Most candidates demonstrated a good understanding of the change in speed and wavelength when the ray of light passes from Perspex™ into glass.

Question 7

Answers ranged from excellent for candidates who clearly had a good understanding of superposition and path difference to those whose understanding restricted their ability to gain good credit for this type of question.

(a) Some candidates gave excellent answers in terms of superposition and path differences between the reflected and direct wave as the aluminium sheet moves. A significant number of others attempted incorrectly to explain what was happening in terms of amplitude changes and thus changes in intensity as the sheet moved closer to the emitter. Other incorrect responses included an explanation in terms of a standing wave set up between the emitter and detector.

(b) The candidates who had not correctly answered **part (a)** tended to be candidates who did not gain the marks for this part of the question. Many candidates did not seem to appreciate that there was a path difference between the direct and reflected wave and that it was necessary to determine this. Answers often attempted to find data to put into the equation $d \sin\theta = n\lambda$ or determined the difference between the two maximum readings given in the question as the value for the wavelength. Such approaches were often accompanied by a maze of seemingly unrelated equations that gained little credit. A few candidates who had correctly calculated 3.06 cm for the wavelength gave an incorrect conversion into metres.

(c) As in **part (b)** candidates who had incorrectly answered **part (a)** were candidates who were less likely to gain the marks for this part of the question. Some candidates gave excellent answers scoring full marks. Many others gained no credit for other responses, for example: ‘incorrect rotation of the waves’ or ‘destructive interference with itself’ or ‘diffraction very low’ or ‘forming a node’. Some gave extensive responses that also did not qualify for a mark for example: ‘when waves no longer in phase they undergo interference resulting in a decreased amplitude and therefore decreased intensity’.

Question 8

The instruction in the question ‘explain what can be deduced from this information’ generated a wide range of responses. Answers ranged from the few candidates who scored the full 8 marks to most candidates who scored somewhat fewer marks. It was pleasing to see the number of candidates that were able to determine the two half-lives from the graphs. Fewer candidates extended this to determine the decay constants.

Most candidates showed a good understanding of what was represented by the two graphs. Some missed opportunities to link information from the graphs to what this physically represented. Many described the graphs in some detail as, for example: ‘exponential’ or ‘increasing and then decreasing in count rate for nuclide Y’ or ‘the two count rates crossing over’ or ‘for Y a maximum count rate then slowly decreasing to zero’. It was difficult to give credit for such statements about the shape of the curve without an associated deduction as to what that represented. For example, ‘after 120 minutes all of Y decayed’ needed to have linked to it ‘because the count rate was zero at 120 min’. Conversely, ‘the count rate was zero at 120 min’ needed to be linked to ‘therefore Y is virtually depleted.’. Several candidates gave general statements about radioactive decay without linking these to the question. These included: ‘radioactive decay is spontaneous and random’; ‘impossible to predict radioactive decay’; ‘probability of decay is constant’; ‘radioactive decay curves are exponential; ‘some radioactive decay is spontaneous and random’.

Few recognised that the shape of the graphs representing a tendency to zero count rate demonstrated that there was no background count included in the data shown on the graphs. A few recognised that the count rate did not represent the number of emissions from the source. Some candidates were able to gain credit for using the area under the graph to find the number of counts and thus the number of alpha decays.

Question 9

Answers ranged from excellent from candidates who clearly had a good understanding of a diffraction grating and of photons to those whose understanding restricted their ability to gain good credit for this type of question.

(a) This had a wide range of responses. Many gained credit for explaining the measurement of the two distances, calculating θ, and the use of $\lambda = d \sin\theta$ to find $f = c/\lambda$. Very few gained the marks for explaining how the direction of the first order could be practically determined or for indicating how the accuracy of the experiment might be improved. Some seemed to confuse this experiment using a diffraction grating with an experiment using Young’s slits. Candidates did not gain credit for incorrectly, using $\lambda = dx/D$, or for using $\sin\theta$ where $\tan\theta$ was appropriate or for using linking phrases to support an incorrect calculation or missing explanation, e.g., ‘you can find’, ‘θ is found using trigonometry’.

(b) (i) This was well answered by many candidates who did show a good understanding of the physics. There were good answers showing how the energy gained by an electron in moving through a potential difference of 2.8 V related to the subsequent photon energy. A significant number of candidates did not gain full credit because of an incorrect use of significant figures in giving a value for the Planck constant.

(ii) This was another question that was very well answered. Most candidates a showed a good understanding of a complex situation and were able to achieve full marks for correctly calculating the number of photons emitted by the LED each second.

Section 2

Question 10

This was a longer question covering a wide range of topics based on material already seen by the candidates. Candidates gave a wide range of responses. Many of these demonstrated careful reading of the Extracts. Candidates gained good marks on the sections with calculations but the sections of the question requiring a more extended written response presented a greater challenge.

(a) Many candidates wrote extensive answers to this question part. The best answers focused directly on the question asked and explained that the wood would release its caloric and commented on the changes that had taken place. For example, these might be the wood changing into ash, water vapour or smoke. Many responses did not answer the question. Explanations were given of caloric between atoms, caloric moving into the wood or caloric causing the wood to burn. None of these explained how the changes produced by burning wood would be explained in the caloric theory.

(b) (i) There were many good answers explaining that the results contradicted the caloric theory because there was seemingly an unlimited supply of caloric. Good responses were also given explaining that the canon and bits machined off had the same specific heat capacities and therefore the same calorie content per kilogramme. Some candidates wrote: 'same specific heat capacities.' With no further detail given it was not possible for them to gain full credit for the question. Candidates should be aware that whilst a detailed response may be required for a question, the response does need to focus on the question asked.

(ii) The question asked whether Romford was right in his claim. The response therefore needed a 'yes' or 'no' with some explanation. Many candidates did not gain the credit because an explanation was given without an indication as to whether this was supporting a 'yes' or 'no' response.

(c) (i) This was a well answered question. Most candidates were able to use the data from the question to show that Joule's measured temperature rise would have been between 0.5 °Cand 1 °C. It was not possible to give full credit to candidates who omitted the effect of a friction at the pulley, or the temperature rise of the brass, $\Delta\theta$, in the calculation. The resultant force was the weight minus the friction at the pulley i.e. 258.0 – 1.8 = 256.2 N.

Energy given to brass = mass × specific heat capacity × $\Delta\theta$. The mass of brass and the specific heat capacity were given in the data for the question. It would have been unusual for data to be given and not used in the question.

(ii) A wide range of responses was given in explaining the two advantages of a procedures that Joule had taken. Many candidates did give answers that appropriately explained the advantages of minimising heat loss and repeating the measurements. From some candidates there were inaccurate suggestions that minimising heat losses improves the precision of the experiment. There seemed to be some confusion between precision and accuracy. In this case it was the accuracy that was improved.

(d) (i) A good set of answers with candidates showing a clear understanding of how to calculate the efficiency of a steam engine. It was necessary to select the minimum sink temperature for the early steam engine of 0 °C rather than a higher temperature. Most candidates did this. Calculations for the efficiency using temperatures in °C rather than degrees Kelvin resulted in a few candidates not achieving full marks for the question.

(ii) This was a well answered question with candidates demonstrating a clear understanding of the reason for inefficiencies in a steam engine. Most candidates gave good answers focused on the issue of lack of insulation leading to his heat losses and friction in the moving parts. Others gave good answers focused on the importance of achieving a significant temperature difference and the difficulties of getting the hot source hot enough or the cold sink cold enough.

(e) (i) This was another calculation that was well answered with candidates showing a sound ability to extract the appropriate data from a question. Almost all candidates were able to calculate the work done per day by dividing the average energy annual energy consumption by the number of days in a year.

(ii) Many candidates were able to accurately use the information COP = Q_C/W given in extract 5 in the Pre-Release material to give a good answer. The responses by a small number of weaker candidates were characterised by a series of unrelated calculations and no reference to the equation given in the pre-release material.

(f) (i) There were a range of candidate responses. The best answers focused on a clear understanding of the COP. A significant number of others were unable to identify how best to approach the calculation.

(ii) Many candidates did not give a direct answer to the question that was asked. The question stated 'with reference to the COP'. Statements were made: 'there was an additional source of energy' or 'more heat was emitted than electrical energy used'. Both of these were true but needed to be related to a COP > 1 to gain a full credit.

(iii) This was well answered. Most candidates appreciated correctly that air-sourced heat pumps were cheaper to install or that less construction work was needed.

(iv) It was pleasing to note that for this last question of the exam paper, most candidates were able to achieve some credit. The best answers clearly explained why ground-source heat pumps have a higher COP value than air-source heat pumps and related this to the COP values. Most candidates were able to identify a factor relating to the temperature. Many stated that the underground temperature was: 'more constant than an air source', or 'higher than an air source' or 'closer to the temperature inside the house'. Fewer candidates gave an explanation as to why the COP was higher (e.g. W reduced) to gain the full credit for the question.

PHYSICS

Paper 9792/03
Paper 3 Written Paper

Key messages

Candidates should read the questions through carefully and consider that earlier, simpler parts may be there partly to help the candidate later.

Candidates must think about the use of formulae. It is wise to write down relevant formula and pause for thought.

Candidates must use their higher-level knowledge and not assume answers that were sufficient for GCSE will get full credit.

All candidates should be able to produce definitions of term. Sometimes, it is wise the write a formula and then define it in words. Going through the specification and highlighting terms that need explanation or definition is a useful revision task.

Candidates should use the space on the answer paper sensibly. They should use medium size writing and start in the top left. Often a few seconds thought before writing will save wasting minutes of time sorting out this issue.

Numbers, especially indices, must be written unambiguously.

General comments

The standard of candidates in the two large entries was very high.

All questions were correctly answered by some candidates.

The comments are aimed mainly at those of high ability but a little below the top marks.

Almost all candidates chose at least two of **Questions 8**, **9** and **10** and there was little difference between the marks of competent candidates on them. 91 per cent did **Question 8** on rotational motion, 81 per cent did **Question 9** on electron orbits and 59 per cent did **Question 10** on fields and Maxwell's equations.

21 per cent did **Question 11** on relativity, 26 per cent **Question 12** on the Boltzmann factor and 25 per cent did **Question 13** on predictability and uncertainty. **Question 12** had the lowest average mark because some candidates chose it despite not having the skills to tackle the algebra involved in using the Boltzmann factor.

Question 1

For Part (a)(i), few candidates were confident about using the term subtended**.** A few did not notice part **(ii)**.

Part (b) (ii) was not done well. Many thought it was like a triangle of forces and many thought the change in velocity vector was away from the centre of the circle. **Part (b)(iii)** was done in many valid ways despite the simple suggestion in the question.

In **part (c)**, a common error was to think the Earth rotated on its axis once a year.

Question 2

The main issue for the whole question was candidates not seeing it as a real situation in the laboratory. Some suggested such things as doing it in vacuum! Some suggestions on improving measurements were too vague. Good suggestions including such things as using a liquid with a lower specific heating capacity or ensuring resistance of leads was small compared with resistance of the heater resistor.

The calculation in **part (d)** was done well.

Question 3

In **part (a)(i)**, using a diagram was an effective way of scoring both marks. In **part (a)(ii)**, many failed to show it was simple harmonic though derived the period equation successfully.

Most candidates scored highly in **(b)** and **(c)**. A couple of candidates lost easy marks by writing 2 and 3 instead of 2.00 and 3.00 in the table.

Most candidates answered **(d)** well but a few made errors in algebra, thinking it was trivial and then using large writing and consequently, having to 'squeeze things in'.

Many noticed the answer to **(e)** was complex and scored the mark. But they did not always relate this to over-damping.

Question 4

This question on fields was answered well by most candidates who were confident in the force and potential equations for inverse square law fields.

Question 5

This question on ideal gases was well answered. In **part (a)(iii)**, candidates would be well advised to think of the points they wanted to make before starting to write. They could halve the length of their answers.
In **part (c)**, many candidates failed to notice the two marks on offer. They were expected to mention intermolecular forces and finite volume of the molecules.

Question 6

The marking of the bonding energy per nucleon graph accepted a range of candidate answers. Only a few candidates clearly recalled its characteristics. **Part (a)(ii)** was not well answered. Candidates rarely made it clear what the words in the question fission and fusion meant. They also failed to use per in the key words *per nucleon.*

In **part (b)**, many did the calculation with great confidence, but some stopped halfway through and only gave the energy per uranium nucleus. Most candidates would gain marks and save time if they set out a 4-mark calculation in an organised fashion.

Question 7

Half the candidates could draw the Balmer lines though more recognised the 3 to 2 change.

Part (b) was done well by most.

SECTION 2

Most candidates chose at least two of **Questions 8**, **9** and **10** and there was little difference between the marks of competent candidates on them. Those who chose from **11, 12** and **13** tended to do very well or struggle to score half marks.

Question 8

Part (a) asked how it would feel turning the handle. Many suggested applying, say, a constant torque. They were trying to be what they saw as 'scientific'.

In **part (b),** it was clear some had tried the question when they did not understand the basic ideas of the topic like relating angular velocity of a wheel to speed.

Part (c) on energy was better.

Candidates were well prepared for the integration in **part (d).** They took different, equally valid approaches.

Many candidates seemed to favour 'suvat' approaches and so, although they could do **(i)** without considering energy, **(ii)** proved too challenging. A couple of candidates did manage **(ii)** without using energy. **Part (c)** on energy was partly a prompt for **part (e)**.

Question 9

Part (a)(i) was well answered. The main fault in answers concerned the limits of integration.

Parts (b)(i) and **(ii)** were done very well but answers to **part (iii)**, even from very good candidates, were too vague when the information was there to determining the energy increased by a factor of 64.

Part (c) was worked through competently. However, almost all candidates should set out their working as if it were to be understood by a fellow candidate not just an experienced Examiner. **Part (v)** threw up some extraordinary answers along the lines of 'computer says nought'. Calculators overload at 10^{100} but some candidates could not see this despite probably knowing the answer was 13.6 eV in joules.

Question 10

Part (a)(i) was well answered but **(ii)** showed many candidates were not clear about the forces on a moving charge in a magnetic field.

Part (b) was answered well but many candidates are not clear about what is meant by 'the charge' on a parallel plate capacitor.

Most candidates successfully worked through the derivation. A few very good candidates got caught out by the calculation in **(vi)** thinking they knew the answer.

Question 11

Part (a)(iii) was not well answered. Candidates failed to appreciate the times were very close so any approximation needed to be done after the subtraction.

Part (b) was adequately answered but, in **(c),** candidates really liked using special relativity; it was very well answered.

Question 12

The best candidates who tackled this question got 19 or 20.

Part (a) was answered well except for **(vi)** where some candidates struggled with the algebra of the Boltzmann factor.

These same candidates found the same difficulties in later parts. The introduction did let them know that it involved the Boltzmann factor.

Question 13

A wide range of candidates tackled this question despite it starting with a very clearly philosophical passage. For many of the lower scoring candidates it was their best optional question.

Though the candidates understood the question as a whole, **(c)(iii)** was not well answered. The idea of an incredibly huge number of random events leading to a 'certain' outcome had not been grasped by many candidates.

However, the idea of the arrow of time in **part (d)** had clearly caught the candidates' imagination. In **part (d)**, many candidates referred to the arrow of time, linking it successfully to the impossibility of Laplace's Demon.

PHYSICS

Paper 9792/04
Personal Investigation

General Comments

Centres have again encouraged candidates to complete a good range of interesting Personal Investigations. It is also clear that Centres take a large amount of care both with the administration and marking if the investigations including appropriate (often robust) ‘internal standardisation’ processes.

Centres are reminded that a ‘best-fit’ approach should be used when applying the criteria to an individual candidate’s plan and report. Centres need to be wary of giving a higher mark by giving the benefit of the doubt (BoD). Throughout the criteria, if a Centre believes that a candidate should deserve the higher of the two adjacent marks, on balance, then the script must be annotated and if a similar situation arises later then the higher mark should not be awarded. Annotation of candidates’ work is essential and candidate errors(s) should be highlighted so that the moderator is aware that the Centre has allowed for the errors in the marking.

Again, most differences occur in the award of marks for the quality of physics, use of measuring instruments, data processing and communication. Work that lacks the necessary detail should not be given the highest marks for these criteria.

One of the purposes of the moderation process is to confirm the marks awarded by a Centre. It is thus very helpful where a Centre has annotated the script either to justify the award of a mark or to indicate why a mark has not been awarded. Several Centres enclosed annotated copies of the marking criteria or their own version of the marking criteria. Centres are encouraged to produce a rationale for the awarding of the marks. Both good physics and wrong physics in the candidates’ reports should be highlighted to judge the award of the appropriate mark. In Centres with several teachers marking the work, it is helpful if all the teachers marking the work give similar rationales.

Candidates should be encouraged to include photographs of sophisticated procedures. Candidates should also not be concerned about producing computer generated diagrams – labelled hand-drawn diagrams are acceptable and often give better detail. Candidates should also avoid just producing excel graphs without thought to the scales and axes; some of the graphs produced using ‘Excel’ were very difficult to interpret and often lacked explanation from the candidate. Where large quantities of data are collected, good candidates record the data in clearly labelled appendixes.

Comments on applying the criteria

Initial planning

For the award of two marks candidates must include a summary of how the investigation might develop. Four marks should be awarded for appropriately detailed work which should include an explanation of how the pilot experiment has helped to determine how the investigation may develop.

Organisation during the two weeks of practical work

Centre’s comments were very helpful in justifying the award of the marks. Candidates’ reports often had dates written in the report which helpfully show the progress through the investigation. For the award of two marks, Centres should be satisfied that candidates are analysing and interpreting each experiment as it is completed. It is helpful where Centres indicate this in the report.

Quality of Physics

This criterion tends to be generously awarded particularly for higher scoring candidates. Good candidates explained how the Physics used was related to their investigation. For six marks, candidates should be explaining Physics which goes beyond the taught course and their explanations should be both clear and without error – it should not be copied sections of reference material or textbook. In some cases, there were investigations which were quite straightforward but were generously awarded high marks for this criterion. For the award of four marks, principles of physics should be used to clearly interpret results.

Centres must highlight errors in the Physics, so that it is clear that the error has been allowed for in the marking. There should also be evidence of how Physics principles are used to explain a candidate's results, in the candidate's own words.

It is helpful where Centres justify the award of the marks in this criterion with a written comment.

Use of measuring instruments

For the award of two or three marks, two experiments must have been undertaken and some further attention is needed to the measuring instruments used. When data logging equipment is used, there should be some explanation in the report as to how the equipment is being used. This applies to the use of light gates and motion sensors. For the award of three marks, the apparatus should be either sophisticated or uses a creative or ingenious technique. Some candidates helpfully included photographs showing the experimental set-up of their apparatus.

Practical Techniques

Good candidates carefully explained their reasoning as their investigation progresses. Candidates should be analysing their results as the investigation proceeds and as a result it may be necessary to repeat readings or take additional measurements near any turning points. Candidates should be encouraged to record their reasoning for additional readings.

For the award of the higher marks, it would be helpful if candidates could include an explanation in their reports of how they are considering precision and sensitivity. The advantage of this approach is that it will assist candidates in the data processing criterion when explaining the size of the error bars.

Data processing

This area was still generously awarded particularly for higher scoring candidates. Some candidates produced many 'Excel' graphs without much thought to scales, number of plots, lines of best-fit and the analysis of the data. Where 'Excel' graphs are included, they should be presented correctly with axes labelled clearly with an appropriate number of data points and trend lines fitted correctly. The highest marks should not be awarded for excel graphs which lack appropriate scales or with poor lines of best fit.

For the data processing to score good marks there must be clear explanation of how the experiments are being analysed. A good number of the more able candidates successfully plotted log-log graphs to test possible power laws. Often their work was supported by detailed reasoning.

For the award of the higher marks, there does need to be some sophistication in the work and clear reasoning. Where candidates add error bars to their data points, they should include a clear explanation of how the uncertainties, and the uncertainties or error bars, have been estimated.

Communication

It is also expected that candidates who are achieving the highest marks in this area include aims and conclusions for each practical and for any mathematical analysis. This particularly applies to the treatment of uncertainties. Candidates should also account for any changes in their original plan.

More candidates are including glossaries and detailed references which include page numbers. For the highest marks, the report should clearly show development and feedback between experiment and analysis. References used should enhance the report. It should be noted that for the award of four marks, sources identified should include page numbers. References should clearly indicate how the material has been used to enhance the investigation.