PHYSICS

Paper 9792/01
Multiple Choice

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

General comments

Candidates again appeared to have been prepared well and have a good understanding of all parts of the syllabus. There appeared to be a greater balance between ***Section A*** and ***Section B*** of the syllabus this year. ***Section A*** had nine questions which candidates found straightforward whereas ***Section B*** had seven. The most difficult question this year on the whole paper was **Question 8** on part A of the syllabus. On ***Section B*** of the syllabus, **Question 31** appeared to be the most difficult.

More able candidates tend to perform well across the syllabus topics, weaker candidates tend to find the ***Section B*** topics more difficult. A number of candidates scored full marks.

Please note that due to an issue with **Question 22**, this question has been cancelled. Candidates' marks have been multiplied by a weighting factor so that the maximum mark for the paper remains unchanged.

On part A of the syllabus, **Questions 1**, **4**, **5**, **6**, **7**, **10**, **13**, **15** and **17** appeared to be straightforward.

On part A of the syllabus, in addition to **Question 8**, low scoring candidates also found **Questions 12** and **16**, to be challenging.

In **Question 8**, candidates needed to identify the correct change in temperature when using the specific heat capacity equation. Very few candidates chose option **D** where the melting of the ice has been avoided.

High scoring candidates correctly answered **Question 12**. Other candidates correctly identified the charge in resistor Z but did not use the appropriate equation to determine the energy in resistor Z.

High scoring candidates correctly answered **Question 16**. Other candidates tended to choose answer **C**.

On part B of the syllabus, **Questions 21**, **27**, **28**, **32**, **34**, **36** and **39** were well answered.

On part B of the syllabus, in addition to **Question 31**, low scoring candidates also found **Questions 24**, **25**, **30**, **35**, **37** and **38** to be challenging.

In **Question 31**, the common incorrect answer was **C** – candidates not fully understanding that the velocity of the charged particle is proportional to the square root of the potential difference. Approximately half the candidates scored a mark in this question.

In **Question 24**, the common distractor was **B** where candidates did not realise that the tension would be a maximum at the lowest position.

In **Question 25**, the common distractor was **A** where candidates did not correctly consider the direction of the electric field at point X.

In **Question 30**, the common distractor was **B** where candidates did not use the correct distance.

For **Question 35**, candidates often calculated the total energy of the annihilation.

In **Question 37**, the majority of the high scoring candidates scored the mark. Candidates should be encouraged to eliminate answers in these types of questions. The other responses were chosen equally by low scoring candidates.

In **Question 38**, the common mistake was to omit the ground state from the calculation. Again, high scoring candidates scored this mark.

PHYSICS

Paper 9792/02
Paper 2 Written Paper

Key messages

On this paper and at this level, there is inevitably a significant variation in the standard of the questions; some are fairly direct and straightforward whilst other require some thought and involve a certain amount of working out. These latter questions can be quite challenging. Other questions range somewhere in the middle between these two extremes. For all questions, however, a confident familiarity with the appropriate section of the syllabus is needed and this can only be achieved by approaching the course with a consistent diligence followed by a thorough revision that begins to produce an appreciation of the many connections that link the different topics and techniques.

There are occasions when the answer supplied by the candidate does not match what is expected and this can lead to lost credit or to a waste of time. Two major indications to the type of answer expected can be found on the question paper. The command word used in the question itself is the more significant of these and the import of the word and what it suggests can be found in the glossary of terms in the syllabus. Although the list is not exhaustive, it does include all of the most commonly used terms. The second indication is the mark allocation which can be found in square brackets at the end of each part.

Less important, although more obvious perhaps, is the number of answer lines or the size of the answer space provided. The answer space does need to accommodate the type of answer expected but it also has to allow for those few candidates who have unusually large handwriting and for candidates who might wish to cross out and replace some or all of their first attempt at an answer. It should not be taken as a direct indication of what is wanted

General comments

The examination is designed so that most candidates have enough time to complete it and to carry out a little final checking of what has been written but there ought not to be much time to waste and so in the examination, candidates need to allocate their time appropriately and in a way that to some extent reflects the marking allocation. Some questions take more time than others, of course, but even the most elaborate and detailed answer to a short and simple question cannot make up for an incomplete and cursory response to a more challenging question.

In calculations, it helps to set work out neatly and in an orderly manner and to check that common errors are not made. Even at this level, an equation such as $x = yz$ is far too often seen rearranged to give an expression such as $y = z/x$ or similar. Likewise, a term that is squared in an expression written in the answer space is not squared when the numbers are entered into a calculator. This gives an incorrect final answer. It is also not unknown for candidates to enter a number in standard form incorrectly in a calculator. This is more common when the exponential button is labelled *EXP*, *EE* or something similar rather than being labelled $\times 10^X$. A number such as 1.72×10^{-5} can easily be entered as $1.72 \times 10 \times 10^{-5}$. Care is needed.

Comments on specific questions

Question 1

(a) Almost all candidates were able to state the difference between velocity and speed. It is worth noting that one consequence of the wording of the question is that candidates who only use the term *it* or who are rather vague in a similar way can be assumed to be referring to velocity.

(b) (i) This part was well answered by a large number of candidates. There were a small number of candidates who correctly wrote 13.1 × sin(15.0°) but whose final answer was not correct. It appeared that some of these candidates were using a calculator that supplied the sine of 15 radians. It is well worth checking that calculators are set up in the way expected.

(ii) This part was also answered correctly by a large number of candidates. There was, however, a small minority of candidates who calculated the answer using the horizontal component of velocity even though the vertical component had been used in part **(b)(i)**.

(c) Although the statement of Newton's second law of motion in terms of momentum was commonly seen, there were some answers that stated the principle of the conservation of momentum or that made no reference to momentum.

(d) (i) A large number of the answers were correct. Full credit was not awarded when 4.00 cm was taken to be the radius of the circular hole. A second source of inaccuracy was the use of 13.1 rather than 13.1^2 in the calculation. There were those who did this even though 13.1^2 had been written down previously.

(ii) Many candidates were uncertain about what was expected here and a variety of answers was supplied. The effect of friction was the most common of these.

Question 2

(a) (i) There were a large number of correct answers given here. Almost all candidates referred to the need for no resultant force although rather fewer made mention of the absence of a resultant moment. Some candidates stated that there should be no resultant vertical force and no resultant horizontal force as the two conditions; this was not awarded full credit.

(ii) Although the correct answer was seen quite commonly, a significant number of candidates did not apply the principle of moments in the correct way and were not awarded full credit. A few candidates wrote an answer that was exactly half of the correct value because only one supporting cable was considered. Although the time spent on each part has to be considered carefully in this examination, it is always worth while ensuring that the exact information given is understood.

(b) This part was very frequently answered correctly. There were a few candidates, however, who gave answers that were too large or small by multiples of ten. There are many possible explanations for this but it is clear that there are candidates who are not clear about entering numbers in standard form into their own calculator.

Question 3

(a) Very few candidates answered this part well. It was only a very small minority that used a potential divider circuit or an equivalent approach. Likewise, there were many circuits that omitted the voltmeter, the ammeter or both. Those that included them, usually placed them in the circuit correctly.

(b) (i) This was very often correct with only a few candidates using the final gradient or dividing the final current by the final potential difference.

(ii) The most common answer given here was 0 (Ω). Of those candidates who used the gradient at the origin, the majority obtained an acceptable value for the resistance.

(iii) There were many good answers but there was also a variety of answers that were not awarded full credit. A current that increased gradually at a decreasing rate to a final value was quite common.

(c) This equation was often shown to be correct by candidates who produced some significant detail. When credit was not awarded, it was often because a correct equation using the final terms was written down and then rearranged. This approach did not indicate where those terms had come from or why the initial equation was appropriate.

(d) (i) This straight line was almost always drawn correctly. A rather small number of candidates misplotted the right-hand point or very occasionally plotted it so carelessly that it was not sufficiently close to the correct position. There were also a very few lines that were either not straight or which did not seem to be related to the equation in the question.

(ii) There was a mixture of answers here. Many candidates realised that the point of intersection of the two graphs could be used to obtain the answer. A common answer, however, was ~7.8 V rather than 12.0 – 7.8 V. Candidates who, rather than using Fig. 3.2, attempted to calculate an answer were very rarely awarded any credit.

Question 4

(a) Although a significant number of candidates stated that the point of application of a force was moving through a distance or gave an equivalent statement in terms of pressure and volume, many answers were too vague or imprecise.

(b) (i) This calculation was preformed correctly in almost all cases. The graph, however, was labelled in terms of kN and cm and this led to some answers that were too large or too small by multiples of ten.

(ii) Most candidates realised that the work done on the gas corresponded to the area under the graph and then determined a value for the work done by counting squares or some equivalent procedure. This led to answers that were to a greater or lesser extent acceptable and the credit awarded corresponded to the accuracy of the determination. There were candidates who simply multiplied the final force by the final value of the x. This generated an answer that was far too large.

(iii) Most candidates stated that the kinetic energy of the gas molecules increased. Only a minority tried to explain how pushing the piston into the cylinder caused this increase. There were many answers which were concerned with the increased rate of molecular collision with the piston which is not part of the explanation.

(c) (i) It was only a minority of candidates who realised that the work was done on the piston by the expanding gas was greater than that done on the gas previously. Few of these explained why this was the case. There were many answers suggesting that the two quantities were equal or that they only differed as a consequence of friction between the piston and the cylinder.

(ii) Most, but not all, candidates were able to state what a heat engine does.

Question 5

The answers here varied considerably with some candidates not knowing how to proceed at all. Many candidates, however, recognised the graph and realised that it was possible to deduce the wavelength of the light. A significant number of these, however, took the slit width as the separation of the slits and used the wrong equation at this stage. Using this value some candidates deduced a different slit width which was greater than the separation.

There is often credit available in a question such as this for making one of several comparatively straightforward statements or observations. When candidates make these comments, it often seems that they have been made as a passing comment rather than as a deliberate statement. In this question comments such as *the light is monochromatic*, *this is an interference pattern* or *background light is reaching the sensor* were only made by a small number of candidates.

Question 6

(a) Almost all candidates received some credit and a smaller number were awarded full credit. The overwhelming majority of candidates gave answers that seemed to imply or at least suggest the presence of physical particles vibrating. Only a handful of candidates gave answers in terms of varying electric and magnetic fields.

(b) (i) This was almost always correct. A few answers of the form *It is the same*, were too vague to gain any credit.

(ii) This was very frequently completely correct. A |cos| graph was the most common graph that did not receive full credit

(c) There were many good answers here. Some candidates either confused the angle with its complement or omitted to square the cosine function when calculating the answer. This included many candidates who had just sketched a $\cos^2$ graph in the previous part.

Question 7

(a) (i) Although, in this part, there were many good drawings that were awarded full credit, a noticeable minority of the drawings were less satisfactory. Some drawings did not include any labelling or did not label in an acceptable manner the electrons or the neutrons. There were several drawings that showed 6 electrons orbiting the nucleus.

(ii) It was very unusual to see an answer that was not awarded full credit here.

(b) (i) A large proportion of candidates supplied very satisfactory answers here. Answers that were not awarded full credit were mainly in two categories. Some answers gave little in the way of explanation and simply gave a statement such as *the nucleus is small* and not much more. Other answers explained why a small minority of alpha-particles do not pass through the gold sheet in a straight line and out the other side. This was not what was asked for.

(ii) Many answers in this part were awarded full credit. Some candidates who did make reference to the charged nucleus, did not, however, point out that the deflection was due to the repulsive force that was a result of the charges present.

(c) Most candidates gave good answers and a sensible reference to the ionisation properties of alpha-particles was almost universal. The penetration property of the particles is also relevant but some candidates referred to this in the most general terms which did not constitute an explanation of the form required here.

Question 8

(a) The overwhelming majority of candidates were able to calculate the correct answer and full credit was awarded very frequently. Where full credit was not awarded, the most likely cause was inaccurate arithmetic. Some candidates either lost the factor of ½ somewhere in the working or divided by 2 rather than by ½ when rearranging the numbers. A few candidates did not take the final square root and obtained a speed that exceeded that of light. The correct calculation gives an answer that can be rounded to 8.00×10^6 m s^{-1} but which does not equal this value exactly; it should not be expressed as 8×10^6 m s^{-1}.

(b) Many answers were awarded full credit or nearly full credit. Nearly all candidates realised that this is a demonstration that shows electron exhibiting wavelike properties. Just a very few candidates stated that the separate rings in the pattern corresponded to energy levels in the crystalline material.

(c) Most candidates realised what was expected and calculated an appropriate diameter for the aperture.

Question 9

(a) (i) Most candidates completed the equation correctly. There were a few –1 subscripts for the neutrino.

(ii) There were many correct answers. Two common inaccuracies were to omit the tick in the hadron box for the neutron and to classify the β^+–particle as a meson.

(b) (i) This was largely answered correctly; some candidates did not indicate the distances at which the strong nuclear force becomes repulsive.

(ii) Most answers referred to the Coulomb force in some way but rather fewer mentioned that it is the protons on which this force acts.

(iii) This part was not answered so well. Many candidates related the area to the work done or to energy transferred but the strong nuclear force was not always mentioned and rather few candidates made any mention of the movement from infinity (or ~ 2.5×10^{-5} m). An unfortunate interpretation was to assume that *area* meant little more than *this vague region*. Answers such as *In this area the force is attractive*, were not accepted.

(c) (i) The point labelled E was very rarely marked at the minimum of the potential energy curve. Many candidates marked it where the curve crossed the axis or at a point somewhat to the right of the minimum.

(ii) Many candidates gave answers here which matched an erroneous positioning of the point E in the previous part; no credit was awarded for this and so credit was only awarded occasionally.

(d) (i) This was well answered and full credit was very frequently gained.

(ii) This was also well answered and full credit was awarded almost universally.

(e) (i) Many candidates realised that it was essential that it was necessary for the charges on the two sides of the equation to balance and full credit was awarded often.

(ii) This was usually well answered with the overwhelming majority of candidates calculating the strangeness on the two sides of the equation and showing that the two values were not equal.

(f) (i) This was usually done correctly although a there were a few candidates who did little more that write down $BQv = ½mv^2$ and then cross through a few terms. A brief explanation is often helpful in questions such as this.

(ii) The answers supplied here varied in quality very considerably. Some candidates drew an appropriate, clearly labelled vector diagram and very swiftly reached the correct answer. Other answers did not include a vector diagram of any sort or included a great deal of complicated trigonometry which did not, in the end, lead to the correct angle being obtained.

PHYSICS

Paper 9792/03
Paper 3 Written Paper

Key messages

- Many candidates would have benefited from reading the questions more carefully. The fact that all candidates finished the paper suggests that time pressure was not an issue, so candidates should be encouraged to spend a little more time reading the questions before answering them (particularly when they are selecting questions in ***section 2***).
- On ***section 2*** many candidates simply went for the first three (mathematical) questions. Whilst this was clearly the correct choice for most of them, some struggled on at least one of these questions and might have done better if they had read through all the questions and considered doing at least one of the more philosophical questions.
- It was clear that some candidates (including strong candidates) had failed to learn basic laws and definitions so that, whilst they could use them to solve problems, they could not state or explain them.
- Command words such as 'show' require intermediate algebraic steps to be shown and justified. Some candidates effectively restated the target result without showing how it was obtained.
- When asked to define a term, words must be used. Some candidates simply quoted an equation without saying what each term in the equation represents.
- In longer calculations worth 3–5 marks many candidates simply write down numbers without any algebra or explanation. If this results in an incorrect result it is very difficult to give any credit for intermediate steps.

General comments

- All the marks on each question were accessible although some were more difficult to gain than others (often the ones requiring a written explanation).
- Excellent answers were seen to all questions.
- Few candidates attempted more than three optional questions and, if they did, it was because they found one too hard and selected another instead. No one attempted all six.
- Once again, the majority of candidates selected the first three optional questions (**Question 8**, **9** and **10**) but good answers were seen to all six questions in ***section 2***.

Comments on specific questions

Section 1

Question 1

A significant number of candidates could not give a clear statement of the meaning of centripetal acceleration.

Many candidates could not explain how or why the tilt made cornering more comfortable although they could show the derivation in **(b)(ii)** and sketch the graph in **(c)**.

Some answers to **(d)** reinforced the idea that whilst the candidate was able to carry out correct calculations, they found it much harder to interpret the physics.

Question 2

Most candidates gave good answers to all parts of this question. A few completed the table to 2 sig. figs. rather than at least 2 decimal places (missing the significance of logarithms).

Many lines were drawn carelessly on the graph (without a balance of data points on either side).

A large number of candidates did not calculate time constant from the gradient (not reading the question) and tried to calculate it from one data point.

Question 3

Many answered this question well except for part **(d)(ii)**, not recognising that there would be a distribution of energies/speeds.

A significant number failed to define gravitational potential energy correctly, with many equating it to the work done to separate the bodies.

A common error in **(d)(i)** was to treat the hydrogen molecule as a hydrogen atom.

Question 4

A significant number of candidates found this question challenging and it was clear that many were not confident about electromagnetic induction.

Very few candidates could give clear statements of Lenz's law in **(a)(ii)** and not many stated that the ends of the blades would be at the same potential and hence the p.d. would be zero **(biv)**.

Part **(b)(iii)** was poorly answered, with the majority claiming that the outer end would be at a higher potential because of its greater speed, rather than using the left hand rule or Lenz's law.

Question 5

Candidates from some centres did not seem to be familiar with Brownian motion whilst those from other centres could give very clear descriptions and explanations.

Many could have drawn the curve showing the inverse relationship in **(c)(iii)** more carefully ensuring that it showed and inverse relationship.

Question 6

There were few very good answers to this question. Many did not see that the mass of uranium was 52 mg not 52 g and some took this to be 52×10^{-3} kg instead of 52×10^{-6} kg.

Many struggled with **(a)(iv)**, confusing activity with the recorded count rates.

Many would have benefitted from reading the question more carefully rather than giving stock answers.

Question 7

There were few very good answers to this question. Surprisingly, many did not know Hubble's law. The question asked about principles and observations but candidates did not give adequate responses and either did not know of these significance differences or did not think clearly. Again many would have benefitted from reading the questions more carefully and structuring their answers accordingly.

In **(c)(ii)** the majority of candidates gained 1 mark for realising that if time is reversed the galaxies occupied a much smaller volume but failed to link this to Hubble's law to show that they all originated from the same point at time zero.

Section 2

Question 8

There were many excellent answers to this question but also a significant number of very poor answers, suggesting that these latter candidates might have been better served by selecting a different question.

In **(b)(iv)** a significant number of candidates incorrectly derived the correct expression for the moment of inertia of the rod about its CM by simply substituting *L*/2 into the previous expression for moment of inertia about one end. This was not credited.

Quite a number used linear kinetic energy rather than rotational kinetic energy in **(c)(ii)** and a significant number tried to use conservation of rotational kinetic energy rather than angular momentum in **(d)**.

Question 9

There were many excellent answers to this question. Those who set out their working clearly in part **(c)** were usually more successful. Many scored high marks even if they made a small error in the working.

Surprisingly many did not explain large amplitude oscillations in terms of resonance.

Most were able to carry out a suitable test in **(f)** but a significant number did not provide any reasoning for their conclusion. Whilst the calculated values of k varied they did not show any consistent trend and the variation was not large, so the expected conclusion was that the relationship was probably valid. If they disagreed with this, it was not sufficient simply to state that because values of k vary then the relationship is not valid, there also needed to be a reference to the amount of variation.

Question 10

Most of those who attempted this question gained high marks.

Quite a large number did not know that $L = mvr$ and did not know that angular momentum would be conserved in the interaction.

There were many good clear derivations in **(b)(ii)**.

In **(b)(iii)** a significant number simply stated that radius would be quantised because only an integer number of wavelengths 'fits' the circumference of the electron orbit. However, this alone is not sufficient because wavelength depends on velocity as well and it is not clear from this that radius is discrete, only the product of radius and velocity. Some candidates gave very good answers to this part by using the relationship in **(b)(ii)** and the energy levels of the hydrogen atom to derive an equation for *r* in terms of *n*.

Many were able to calculate the change in radius successfully although this was more challenging, and a significant number failed to score any marks in **(c)(ii)**. A significant number also failed to gain some of the marks because of failing to convert eV to J.

Question 11

Although there were a few strong responses, candidates generally found this question more challenging than the previous three. Too many candidates gave unstructured rambling explanations that often repeated themselves, rather than giving a clearly structured logical answer that focuses on physical principles.

Most candidates understood the details of the Michelson–Morley experiment although quite a few could not explain the significance of rotating the apparatus and fixated on the importance of location rather than relative motion through the aether.

In **(c)(i)**, **(ii)** and **(iii)** a significant number of candidates introduced new variables that were not given in the question.

Part **c(iv)** was very poorly answered and only a handful appreciated the significance of simultaneity, or lack of it. Most candidates simply referred to time dilation and length contraction.

In **(d)** quite a few confused $1/\gamma$ with γ.

Question 12

In **(b)** few appreciated the significance of the collimator.

The calculations in **(c)** and **(d)** were done successfully and there were good attempts at **(e)**.

Most candidates who attempted this question were able to score many marks on parts **(f)(i)** and **(g)** even though they were not able to express themselves clearly or concisely. However, in **(f)(ii)** there were few who could explain what is meant by non-locality, often repeating (in different words) what they had said about indeterminacy in **(f)(i)**.

Question 13

Only a few candidates attempted this question and there were even fewer adequate answers to part **(b)**. These tended to be weaker candidates who knew about entropy increasing and the thermodynamic arrow but not much more.

A common error in both parts of **(b)** was to confuse Q and T and to treat both as energies but it was also clear that some candidates had no idea how to relate the information given to the second law.

PHYSICS

Paper 9792/04
Personal Investigation

General comments

The success of the Personal Investigation is very much due to the time, effort and care of the teachers within each centre. Centres have again encouraged a good range of interesting Personal Investigations. Good candidates clearly enjoy the experience. It is clear that centres take a large amount of care marking the investigations. It was clear that centres where necessary had carried out an appropriate (often robust) 'internal standardisation' process. Centres also take great care in the administration of the moderation process.

For the future, when submitting the sample, centres are asked to ensure that the candidate's number is also included on each investigation and only one copy of the investigation for each candidate in the sample needs to be submitted.

Centres are reminded that a 'best-fit' approach should be used when applying the criteria to an individual candidate's plan and report. It was pleasing to see that the '0' mark was being awarded appropriately in some cases. Centres need to be wary of giving a higher mark by giving the benefit of the doubt. Throughout the criteria, if a centre believes that a candidate should deserve a higher of the mark, 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, data processing and communication. Work that lacks the necessary detail should not be given the highest marks for these criteria. There was a tendency to give benefit of doubt marks to higher scoring candidates particularly regarding 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 which produced a rationale for the awarding of the marks were particularly helped in the justification of the marks awarded. Both good physics and wrong physics in the candidates' reports should be highlighted to judge the award of the appropriate mark.

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. Several centres included candidates' laboratory books which indicated candidates' progression in their investigation. Other candidates clearly dated their work. 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 write a brief comment.

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 should highlight errors in the Physics, so that the Moderator is aware that the error has been allowed for in the marking. Large quantities of copied Physics from a textbook cannot score the top marks. There should also be evidence of how Physics principles are used to explain a candidate's results, again using the candidates own words.

It is helpful where centres justify the award of the marks in this criterion.

Use of measuring instruments

Some candidates helpfully include photographs.

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. As mentioned in previous years, 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.

Practical Techniques

Good candidates carefully explained their reasoning as their investigation progressed. 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 for candidates of this approach is that it will assist them 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. As has been stated in previous reports, 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. It was pleasing to see that many candidates added error bars to their data points; however, candidates should include a clear explanation of how the uncertainties, and the error bars, have been estimated. 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 error bars have been added, some explanation should be given to the size of the error bars. For four or more marks, there must be some treatment of uncertainties which must be clearly explained. In general candidates should be encouraged to explain how they are determining an uncertainty.

Communication

The marks in this section were a little generous in places. Some of the reports were excessively long and thus were not well organised and did not have a clear structure. These reports should not be given six marks.

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.