PHYSICS

Paper 9792/01
Paper 1 Multiple Choice

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

General comments

Candidates again appeared to have been prepared well and have a good understanding of all parts of the syllabus. ***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 ***Section A*** of the syllabus. On ***Section B*** of the syllabus, **Question 25** 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 few candidates scored full marks.

Comments on specific questions

On ***Section A*** of the syllabus, **Questions 1**, **2**, **4**, **5**, **7**, **8**, **13**, **17** and **18** appeared to be straightforward.

On ***Section A*** of the syllabus, low scoring candidates found **Questions 12**, **14** and **19** to be challenging.

Question 12

In **Question 12**, low scoring candidates often added the two emfs together and divided by 2 to gain answer **B**.

Question 14

High scoring candidates usually correctly answered **Question 14**. Other candidates chose each of the of the other distractors.

Question 19

High scoring candidates often correctly answered **Question 19**. Other candidates tended to choose answer **D**.

On ***Section B*** of the syllabus, **Questions 21**, **23**, **24**, **36**, **31**, **32** and **40** were well answered.

On ***Section B*** of the syllabus, low scoring candidates also found **Questions 25**, **28** and **30** to be challenging.

Question 25

In **Question 25**, the common incorrect answer was **B** – candidates not fully understanding that the charge on each capacitor was the same.

Question 28

In **Question 28**, low scoring candidates often chose – omitting the subtraction. Answers **B** and **D** were also common.

Question 30

In **Question 30**, the common distractor was **A** for lower scoring candidates where candidates used the incorrect trigonometric relationship.

Physics

Paper 9792/02
Paper 2 Written Paper

Key messages

- It was sometimes challenging to decipher some of the handwriting. Many set out their responses in a clear way, but a significant number had failed to do this.
- Questions requiring some extended writing giving an explanation in a response were less well answered.
- Questions requiring numerical answers were, for the most part, very well answered although some would have benefited from greater clarity in their explanation. Candidates who did not achieve the correct answer sometimes failed to achieve credit for work done because the working was not clear.

General comments

- This was a very well answered paper. Marks were in the range 21%-97%. Most scored in the 60% to 90% range. No one scored 100%.
- There is much evidence of excellent teaching and learning in many of the responses. Other responses needed to develop a greater clarity and logical presentation to achieve high marks.
- Questions requiring more straightforward numerical answers were well done. Other answers, requiring a written response, needed more detail to achieve the full credit.

Comments on specific questions

Section 1

Question 1

Well answered.

(a) There were many good answers. There were two common errors; using sin 60° or cos 60° instead of sin 30°; when calculating the moment, using the 'distance from the force to a point' instead of 'perpendicular distance from the point to the line of action of the force'

(b)(i) This question part was well answered

(ii) Many candidates did not recognise that the question required taking moments about the support point P. Answers included equating forces rather than moments and including a sin or cosine.

(c)(i) There were many good answers to this but almost all did not follow the question instructions to determine by 'drawing'. Thus, most did not achieve the full 4 marks although some credit was given for answers by calculation.

(ii) This seemed to create a significant challenge to many candidates who did not recognise that the force R calculated in (c)(i) required a force of equal magnitude in the opposite direction.

Question 2

Well answered with most candidates showing a sound knowledge of the deformation of solids.

(a)(i) Well answered; 'drawing a wire' was a common response often mentioned alongside plastic deformation although several candidates did not make it clear that 'ductile' implies significant plastic deformation.

(a)(ii) The responses indicated that candidates understanding of a tough material was much less than that for a ductile material. Answers were frequently given in terms of plastic deformation rather than the ability to absorb large amounts of energy before breaking.

(b)(i) A good understanding of Hooke's law was shown in the responses to this question.

(ii) Mostly well answered; the relationship for the Young Modulus was mostly correctly given but then incorrectly calculated by using' π radius' rather than 'π $(\text{radius})^2$ for the area of cross-section.

(iii) This was less well answered. Many did seem to understand that an external force acting on the copper wire does pull the atoms further apart. However, there were also many who incorrectly gave an answer in terms of the atoms sliding over one another.

Question 3

The 'instruction in the question, 'List what can be deduced', generated a wide variety of responses. These ranged from those answers that scored 8 out of 8 to those that had extensive writing and scored very few marks. There were wide range of responses that could gain a mark. It was pleasing to see how many candidates heeded the question instruction to 'include the relevant calculations. For several calculations, it was not possible to award the relevant mark since the candidate had not made clear to what the calculation referred.

Most candidates seemed to correctly understand that the speed time graph represented a capsule falling off a bridge, hitting the water and then sinking to the seabed. Nonetheless there were a few candidates who looked for a very different interpretation of the capsule falling and gave answers that suggested a parachute and a rising capsule. The use of language to explain deductions presented a difficulty for some candidates with such phrases as 'acceleration slows down' and 'speed changes' being used to explain a change in slope.

The times of hitting the water and sinking to the seabed were well identified as were the slope representing the acceleration and the area under the graph as the distance travelled. Some attempted to use rough estimated for the distance travelled or SUVAT equations. In both cases the values were some distance from those acceptable within the mark scheme range. Attempts were made, also incorrectly, to determine the distance travelled until the capsule hit the water by equating energy changes. Equating kinetic gained to potential energy lost ignored the energy transferred because of the air resistance.

There were some very good responses that included readings from the graph and calculations to give impulse, kinetic energy and resultant force at appropriate times It was sometimes difficult to give credit for a calculation, of e.g., an acceleration, when the candidate had not given the time to which the acceleration referred. This was all the more evident with a candidate response that did not distinguish between average acceleration in air (6.98 ms^{-2}) and acceleration at a specific time in air that might vary between 9.81 ms^{-2} and 3.28 ms^{-2}.

Question 4

The answers to most parts of this question were good

(a) A good set of answers with candidates showing a clear understanding of specific heat capacity

(b)(i) Mostly well answered although many candidates omitted the percentage symbol in their answers and a small number referred to fraction of power/energy or the proportion of power/energy. This suggested the difficulty that some had in reading the instructions in the question that stated clearly 'Define percentage efficiency'.

(ii) A very good set of response; answers demonstrated a clear understanding of calculating power output and the inclusion of the percentage efficiency into the equation.

(iii) This was one of the least well answered question items in the paper. The concept of the power wasted in the transmission cables for the electrical energy from a power station seemed unfamiliar to many. The most common mistake was to determine power P as:
P = (transmission voltage)/(resistance of cables) giving, incorrectly, 7.29×10^{9} Js^{-1}
Very few appreciated the requirement was not to assume that all the power was wasted in the cables but to determine the current I = (output power)/(voltage) and then the power wasted as:
P = I^2 /(resistance of cables)

(c) This yielded a very mixed set of responses. Many assumed, incorrectly, that because the density had changed the pressure on the base must have changed

Question 5

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

(a)(i) Most gave good responses in terms of energy transferred or work done per unit charge. However, alongside those were incorrect responses that ranged from 'difference in potential' to 'I x R'.

(ii) There were a mixed set of answers here too. Many of the responses suggested difficulties the candidates experienced in expressing what they understood. There were phrases such as 'internal resistance known as lost volts', 'potential difference is the work done against the internal resistance' and 'the e.m.f. has an internal resistance'. All these indicated the difficulties experienced by some candidates in explaining what is a challenging topic. Nonetheless none of this should not detract from the many very good answers.

(b)(i) For the most part these were an excellent set of answers with many candidates correctly interpreting the network of resistors and scoring the full three marks.

(ii) Well answered with many candidates showing a good understanding of calculating the potential difference across the terminals of a battery with internal resistance connected to an external resistor.

Question 6

A good set of answers with candidates displaying a sound understanding of waves although many lost credit for omitting to include the necessary detail in their responses

(a) Most candidates were able to explain that electromagnetic waves could be plane polarise because they were transverse. A significant number of responses did not explain that there were many planes of oscillation at right angles to the transmission direction.

(b)(i) The sketch graphs were mostly clearly drawn showing a cos or sine curve with the correct peak separations. Very few seemed to appreciate that a polarised wave would have a lower light intensity than the intensity of the unpolarised light incident on the polarising filter. Thus, the peak intensity of the polarised wave was incorrectly shown as equal to the intensity of the incident wave.

(ii) Many of the responses suggested an understanding of polarisation through several filters. However, as in **Question 5** candidates seemed to experience difficulties in expressing what they understood. There were a range of unclear response including 'light is no longer vertical', 'light diffracted', 'the light is rotated', 'cos θ is now equal to 45°. Many answers did not mention the plane of polarisation, nor make reference to the plane of polarisation of the light leaving the first polarising filter.

Question 7

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

(a) An excellent set of answers with candidates demonstrating a good understanding of the meaning of a longitudinal wave.

(b) Most candidates scored full marks on this question and seemed to have little difficulty in using the relationship $f = c / \lambda$

(c)(i) Understanding the meaning of 'in phase' seemed quite a challenge to many candidates; phase seemed not well understood. Attempting to define 'phase' was sometimes given as an answer. Few were able to give responses that explained that 'in phase' related to a situation where the two waves were always at the same stage of their motion or that compressions/rarefactions occurred at the same time.

(ii) In contrast to writing an explanation about 'in phase' many candidates seemed more comfortable responding to a question that required a numerical answer. Most gained full credit for the correct response although, once again, there was evidence a number of candidates not reading the question a paper. The answer line included the degree symbol and yet there were candidates presenting the answer as $\pi/2$.

(iii) Many candidates scored full marks for this question part although few drew the phasor diagram, as suggested by the question, that might have helped in thinking through the question. A common mistake was adding the two amplitudes rather than determining the hypotenuse of the phasor diagram as $\sqrt{(0.0120^2 + 0.0050^2)}$. A few candidates incorrectly copied part of the data as 0.050.

Question 8

A well answered question with candidates showing a very good understanding of the α-particle scattering experiment and nuclear processes.

(a)(i) Almost all candidates scored full marks describing the α-particle scattering experiment. However, there were a small number of scripts where a candidate did not gain the mark when attempting to describe the experiment in terms of electron bombardment of the gold foil. A few replaced the α-particles with protons. Many omitted to include a vacuum in the experimental arrangement.

(ii) Most were able to explain how the experiment suggested that the volume of the nucleus was extremely small compared to the atom and effectively described that most of the α-particles pass straight through the gold foil. However, there were also many who did not gain the credit for their explanation for why the nucleus might be electrically charged. The α-particle needed to be deflected by a large angle or to 'bounce back' for this to happen.

(b)(i) Almost all candidates determined the neutron number.

(ii) Almost all candidates determined the proton number.

(iii) Candidates were able to demonstrate a good understanding of nuclear fission.

(iv) Understanding the storage of uranium fuel in long, thin rods seem to confuse many candidates. It was frequently suggested, incorrectly, that a chain reaction was prevented because the neutrons were absorbed by the walls of the rod. Typical responses: 'the cylindrical shape absorbs many neutrons'; large surface area allows it to absorb as many neutrons as possible'

Question 9

Mostly well answered overall; there were good answers that demonstrated a clear understanding of diffraction of electrons.

(a)(i) Most correctly answered ‘diffraction’ although a few wrote ‘interference’.

(ii) A good set of answers with candidates showing some degree of understanding of wave-particle duality.

(iii) An excellent set of answers with candidates able to clearly explain the effect on the diffraction pattern of increasing the speed of the electrons.

Section 2

Question 10

This was a more extensive question with candidates expected to be familiar the pre-release material. There were a wide range of responses. In general candidates scored more highly on calculations than on question items that expected them to ‘Show’ or to explain something.

(a)(i) It was clear from many of the candidate answers that they understood what was represented in the cloud chamber photograph. The question asked, ‘how the photograph shows that the particle producing the track is electrically charged’. Many candidates did explain, correctly that the photograph showed a curved track. However, a significant number did not mention the curved track but gave a response that discussed forces on the particle and the factors causing this. Much of this was correct but was not an answer to this part of the question.

(ii) This question produced a mixed set of responses. It would be hard to explain why the track is a proton rather than electron without mentioning the force on the moving particle from the magnetic field and Fleming’s Left-Hand rule. Yet many candidates did do this and in consequence gained very little credit. Answers gaining no credit included: ‘due to curvature in the same direction as the magnetic field’, ‘current is upwards and it must slow down’ , ‘lines at A thicker than at B’.

(iii) In contrast to the previous question part a large proportion of the candidates scored full marks for this question item. Many demonstrated a clear understanding of the energy changes as the charged particle passed through the metal plate and were able to relate their answer to the curved tracks shown in the photograph

(b)(i) Almost all candidates gained full marks demonstrating a good understanding of nuclear transformation equations

(ii) This was another question where candidates seemed to know what was required but found difficulty in writing their answer as a logical series of steps. The question asked candidates to consider momentum to show that the recoil velocity V of the nucleus of mass M is less than 2% of the velocity v of the alpha-particle of mass m. The steps required were:
explaining that the sum of the momenta of the two particles must be zero.
equating the two momenta as MV =mv
this gave 206V =4v and then v/V = 4/206 =0.0194 < 0.02 (2%).
Answers given were frequently scattered with 4/206 without a sufficiently clear statement as to where they were going with the explanation.

(iii) This was one of the less well answered questions. Many had difficulty showing that the ratio of the kinetic energies was equal to the ratio of the speeds for the two particles from the decay. The comments in the previous part apply equally here; many candidates had difficulty in presenting their answer in a logical series of steps. The question gave the answer. Thus, the candidate was required to show the steps between the problem set and the answer given. Inaccurate relationships included: $V^2/v^2 = V/v$; 48.54 = 50. The answers that did achieve full credit worked through the algebra but more often substituted in values for V/v = 4/206 and M/m = 206/4.

(c)(i) A range of answers although most indicated an understanding of the baryon. Sadly, too many simply wrote 210 = 210 as the explanation.

(ii) Well answered with candidates showing a good understanding of lepton numbers. Those that did lose credit failed to give an adequate detail of another particle required to balance the lepton numbers. Too many wrote 'another particle is required'.

(iii) Most understood the significance for the velocity, in the kinetic energy, of the alpha-particle having a mass very much larger than that of a beta-particle.

(d)(i) Well answered with many candidates scoring full marks for using the conservation of momentum to calculate and show the speed of the neutron.

(ii) Calculating the wavelength of the photon produced a range of responses. E= mc2 and E= hc/λ generated the mark scheme response. But credit was given also to those candidates who included a calculation to include the kinetic energy.

(e)(i) This was another question where a candidate was required to show the steps between a problem set and an answer given. Many good answers suggested that candidates were familiar with deriving the relationship between absorption coefficient and the distance required to reduce the intensity to one half.

(ii) The responses indicated that candidates had little difficulty with substitution into the relationship to determine the absorption coefficient. Those that did not gain the credit frequently gave a power of ten as -14 rather than -17.

PHYSICS

Paper 9792/03
Paper 3 Written Paper

Key messages

To read the question right through and consider it as a whole. Early simpler parts have the dual role of testing the candidate and guiding them along the right lines to tackle the more demanding parts.

Use higher level knowledge and not expect answers that were sufficient at GCSE to get full credit at this level.

Think about the use of formulae. There is much more about their use than simply inserting in numbers.

Most candidates know that evidence needs to be given in numerical 'show' questions. In addition to shown working, a few extra significant figures generally provide this.

All candidates should be able to produce definitions of terms. 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.

Use the space on the answer paper sensibly. 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 an answer booklet and crossing out.

General comments

The standard of candidates 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.

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. 92 per cent did **Question 8** on rotational motion, 75 per cent did **Question 9** on electrostatics and 95 per cent did **Question 10** on energy and simple harmonic motion.

Those who chose from **Questions 11**, **12** and **13** tended to do very well or struggle to score marks. 10 per cent did **Question 11** on electromagnetism and relativity, 18 per cent **Question 12** on gas molecules and entropy and 11 per cent **Question 13** on views of interference.

Possibly the topic list issued in the light of the pandemic influenced choice but overall, it seemed to make little difference because the bulk of topics were tested.

Comments on specific questions

Section 1

Question 1

Parts (a) and **(b)** on capacitance were well answered.

In **part (c)(iii)** some candidates failed to notice that since they have just been given a voltage and asked to work out a resistance, they needed to plot the starting current. Also, candidates who had erred in working out the time constant might have noticed the time axes were unsuitable. *Sketch* means use the information readily available to produce a reasonable line.

Question 2

Part (a) was well answered. In **part (b)**, a large variety of arguments were used to show the angular velocities were the same. In **part (c)(i)**, approaches differed but most had the idea of gravitational force being equal to the product of mass and centripetal acceleration.

Part (c)(ii) was not well done. Many candidates forgot gravitational potential energy and those that remembered did not use the skills they had already shown in **part (a)**. A very common error was to think each star had its own gravitational potential energy rather than it being the energy of the system.

In **part (d)** most realised like charges repel.

Question 3

This was done well. A common error was to miss out the factor of 2 in **part (b)(ii)** where the flux linked had changed from a positive value to a negative value of equal magnitude.

Question 4

Many candidates did not realise the question told them about a flawed experiment and was asking them to apply their knowledge to improving it.

In **part (a)** many did not identify the controlled variables: air pressure and amount of gas.

In **(b)** it was clear that a few candidates have not appreciated that the Celsius scale is not an absolute scale like the Kelvin scale.

Part (c) was not well answered even by the most able. Some improvements are: allow for the volume of the sealed tube on the end of the syringe; take a wider range of measurements; use dry air; allow time for temperature of air to become the same as temperature of water. Answers that did not gain credit included: repeat each temperature measurement (impracticable especially if a 0.1°C thermometer used); take a reading exactly every 5°C; plot a graph; record temperatures in K; conduct the whole experiment in a vacuum chamber. Lubricate the gas syringe did gain credit even though this procedure would cause concerns in most laboratories.

Question 5

This question on radioactive decay was well answered but some candidates confused activity with count and did not appreciate the importance of the Avogadro Number in **part (b)(iv)**.

Question 6

Most got the mark for **(a)** saying a standard candle was an object of known luminosity but only some clearly understood their use. Astronomy is clearly a topic taught thoroughly with enthusiasm by some centres/teachers.

Answers to **(b)** varied. Some candidates still seem to think red shift meant the object went red. At this level, mention of spectral lines is expected.

Almost all answers to **(c)** got both marks despite the decimal place requirement. In **(d)**, some graph drawing was careless. All points had to be correct for full credit. In **(e)**, most answers for the intercept were wrong. Candidates at this level should be aware not all graphs show (0,0).

Part (f)(i) was well answered with candidates clearly stating what relationships they were using.

Many answers to **(g)** had error carried forward from **(e)**.

Question 7

This was very well answered by most highly performing candidates. The type of wavelength calculation in **part (b)** was clearly well-practised.

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 marks.

Question 8

Part (a)(i) was done well but fewer succeeded in **part (a)(ii)** often because they did not realise force translated to torque when applying the Newton's Second Law to a rotational system. In **(a)(iii)**, most used the correct equation for rotational kinetic energy, but many got the marks through error carried forward.

The integration in **(a)(iv)** was done very competently and clearly by almost all candidates.

In **part (a)(v)**, most candidates showed that the moments of inertia of the rod and pencil were very different. The few who thought about having the time to correct the wobble achieved the fourth mark.

The show in **(b)(i)** caused few problems but **(b)(ii)** was more demanding and showed which candidates were able to use their knowledge, apply information they were given and calculate in an organised way.

In **(b)(iii)** many candidates forgot that, though the question had primarily been about rotation, translational kinetic energy still existed.

Question 9

Part (a)(i) was not particularly well answered. Candidates should prepare concise explanations or definitions of the concepts in the syllabus. Most candidates understood the distinction between scalars and vectors, but many did not realise that these questions not only tested their knowledge but also were there to help them with later parts of the question.

The integration in **part (b)** was done well.

In **(c)(i)**, some candidates thought it was a vector problem. Many did well especially those who set out their working clearly.

In **part (d)(i)**, many failed to point out N was equidistant from the three charges.

Some failed to notice that **(d)(ii)** was now dealing with electric field strength and the vector calculation in **(iv)** was a good discriminator.

Question 10

Part (a) showed that most candidates not only know but understand the familiar motion equations and **(b)** showed an understanding of the familiar ½ factor.

The calculation in **(c)(i)** was done well but **(c)(ii)** was more challenging with candidates having to think more about the use of familiar formulae. Candidates found **(c)(iii)** straightforward but finding the resultant force for **(c)(iv)** showed some candidates had not clearly adapted a very familiar experiment for Hooke's law to simple harmonic motion.

Good candidates had no difficulty calculating omega in **(c)(v)** but a few did not realise that angular frequency is the name for omega and introduced two pi.

Question 11

Though almost all candidates had drawn circles in **(a)(i)** few realised magnetic field lines are loops and incorrectly wrote field lines go from north to south as if monopoles exist. Some able candidates had gone into the vector algebra of Maxwell's equation in greater depth.

Few candidates in **(a)(iii)** mentioned that the field was changing in size as well as direction. This happened again in **(b)(ii)**. A number thought there was a current between the plates in **(b)(i)**. Faraday's law was well understood in **(b)(iii).**

Part (c)(ii) was clearly answered by some, but many candidates had not learnt what Einstein's postulates are. In **part (d)**, some candidates did not seem to have much experience of using the Lorentz factor especially noticing that v / c is squared. The actual formula is given on page 3 of the paper.

Question 12

The better candidates who did this question did well, but other candidates failed to answer in terms of molecules and in, say, **(c)(i)** recognise molecules were hitting a very quickly moving piston.

In **part (d)** some candidates failed to recognise the importance of absolute temperature. Also, the calculation 4 J / 293 K – 4 J / 253 K seemed to pose great difficulty to candidates.

Question 13

The calculations in **part (a)** were done well by a wide range of candidates. Deciding on whether the route was the shortest route was done surprisingly well considering candidates had to think out a method for themselves.

In **part (b)**, though candidates had just been asked about the two lines predicted by Newton's model, they failed to mention explicitly that multiple fringes would be seen in Young's experiment. Possibly because candidates so often see a laser through a grating, candidates failed to mention the gradual change in brightness for two slits. Many got credit for mentioning the diffraction envelope instead.

In **(c)** the collapse of the Copenhagen wave function was well remembered but several did not take the hint in **part (a)** towards Feynman's approach. The final question got many 1-mark answers. Fewer pointed out that we experience just one universe.

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 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. It was reassuring 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 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.

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 with dates to indicate candidates’ progress during 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 must highlight errors in the Physics, so 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 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. 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.