PHYSICS

Paper 9792/01
Multiple Choice

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

General comments

The paper proved to be appropriately set and all the candidates appeared to answer the paper in the time available. Candidates appeared to have been prepared well and have a good understanding of all parts of the syllabus. There were fewer very difficult questions this year – two on part A and three on part B. Conversely there were slightly fewer very straightforward questions and these all appeared on part A of the syllabus.

On part A of the syllabus, **Questions 1**, **2**, **5**, **13**, **17** and **18** appeared to be straightforward. Generally, these questions either tested recall or application of simple physics concepts. **Question 2** was based on projectiles and **Question 18** required candidates to use an integer number of half-lives from a ratio which in the past candidates have found more difficult topics.

On part A of the syllabus **Questions 11** and **12**, were found to be the most challenging.

Other questions in part A which low scoring candidates found difficult included **Questions 3**, **7**, **10** and **20**.

On part B of the syllabus, **Questions 23**, **26** and **28** were well answered. In **Question 26**, candidates were very able to use the decay equation.

On part B of the syllabus **Questions 31**, **32** and **34** were found to be the most challenging. Other questions in part B which low scoring candidates found difficult included **Questions 24**, **25**, **27**, **36**, **38** and **40**.

Comments on specific questions

Question 3

This question required candidates to correctly resolve vectors and apply the principle of conservation of momentum.

Question 7

Many candidates did not fully understand the definition of work done in terms of displacement.

Question 10

All options were given, evidence some candidates were not fully understanding $I = \frac{\Delta Q}{\Delta t}$.

Question 11

A large number of candidates determined the answer to be 2.5 A, the current through either the top or bottom branches. Candidates needed to apply their knowledge of potential dividers and realise that the potential difference across the middle resistor would be zero.

Question 12

High scoring candidates correctly answered. To achieve success on this type of question candidates may find it helpful to sketch a circuit.

Question 20

This question required candidates to manipulate some algebraic expressions.

Question 24

A common error was not to realise that the energy was proportional to the amplitude squared.

Question 25

The common distractor was **C**.

Question 27

Many candidates determined the electric field strength for only one charge.

Question 31

The common incorrect answers were **A** and **C** – candidates not fully understanding that a change of magnetic flux linkage will occur when the switch is closed and a change of magnetic flux linkage in the opposite direction will occur when the switch is opened. While the switch is closed the magnetic flux linkage is constant and thus the voltmeter will read zero.

Question 32

Most candidates realised that the answer needed to be either **A** or **B**, the issue for candidates was in terms of whether PQ was positive or negative.

Question 34

It was pleasing that few candidates thought that either the mean speed or the root mean square speed would be the same in this question. Low scoring candidates often incorrectly chose **A**.

Question 36

The common mistake was to omit the factor of two for the pair.

Question 38 and **Question 40** are both examples of ratio type questions which low scoring candidates find difficult. There are many topics in the syllabus where candidates could practise these types of skills.

PHYSICS

Paper 9792/02
Paper 2 Written Paper

Key messages

The published syllabus is, of course, the defining document for this examination and the starting point for revision. The different papers are able to assess familiarity with a very significant fraction of the subject matter and so it is essential that candidates are familiar with the entire syllabus. This familiarity is achieved in the years leading up to the examination and it is reinforced and confirmed by an appropriate programme of revision which itself embraces the whole course. This, inevitably, is true for all examinations and whilst a report such as this concentrates on particular skills and approaches and then applies them to the questions that appeared this year, the techniques and procedures, are of limited use if a fundamental grasp of the subject is lacking.

There are many skills needed if an examination paper such as this is to be tackled and although some are almost guaranteed to be required several times in the paper every year, others may only be needed the once if at all. The common skills include the rearranging of equations accurately, the use of calculators and the ability to express an idea in words, simply and unambiguously. These again, are skills that can be learnt gradually and practised as the course proceeds.

General comments

Every effort is made to interpret what has been written but very occasionally a word or comment is simply illegible and cannot even be deduced from context. This might not be of significance but sometimes it can lead to an uncertainty as to what is being stated. This is unfortunate. Some candidates are a little careless when writing numbers and in addition to very common confusion between a 3 and a 5, 4s and 9s can be confused and even 8s and 9s. This is especially the case when the numbers are written as an index. If a numerical answer is to be amended, it is usually better to cross it out and to replace it rather than to write over what has already been written.

Candidates should read the whole question and make sure that it is answered in the terms in which it is asked. It was not uncommon for candidates answering **Question 4(c)(i)**, to answer the question which they guessed had been asked and similarly, in **Question 3(b)(ii)**, the second paragraph of instructions was occasionally neglected. When a calculation includes a number to be squared, it is important that this is done. A few candidates who had written down the square term in the working out in **Question 4(b)(ii)**, did not then square the term when using their calculator.

Comments on specific questions

Question 1

(a) (i) Most candidates gained credit for drawing an appropriate labelled vector triangle. The arrows on some triangles were not always in directions that formed a continuous clockwise or anticlockwise path and it was not always certain which angle was intended to be the right angle. Some common symbols were accepted as labels but candidates should be advised to use notations that are clear and unambiguous. It should be noted that *gravity* is a general term that does not necessarily suggest a force; *gravitational force* or *weight* are much more precise. A few candidates drew diagrams that simply represented the forces and did not include a vector triangle that represented them.

(ii) This was very commonly answered correctly although some candidates took the angle θ as 35.0° rather than as 35.5°.

(b) (i) This part was also well answered.

(ii) This part proved quite challenging for some candidates and very straightforward for others. Common sources of inaccuracy included the confusion of the sine function with the cosine function and a force of friction that suggested that the block was moving up the ramp. Although the mass of the block cancels through in the final equation, some candidates found that they could not reach the end without a value for it.

(iii) The energy transfer to internal energy during the final collision was very frequently but not invariably recognised. That some gravitational potential energy was transferred to internal energy as the block moved down the slope was not always referred to.

Question 2

(a) (i) The limit of proportionality was very often marked in a correct position although a minority of candidates placed it at the first maximum of the curve where the yield point was expected. The question asks for the limit of proportionality to be marked and for this mark to be labelled P. When a candidate used the letter P as the mark, it was not always clear which part of the written letter was intended to be the mark. A labelled dot, cross or small mark of some sort was much clearer.

(ii) This was answered correctly by many candidates although not as many as did so in part **(a)(i)**. The first minimum, the second maximum and the end point of the curve were common erroneous locations for Y.

(b) Many candidates calculated a value for the Young modulus that lay in the range of acceptable values. Only a few candidates did not take into account the fact that the unit on the *y*-axis of the graph was the megapascal (MPa) and produced an answer that was a million times too small. A few candidates who had marked the point P correctly in **(a)(i)** then used the coordinates of a point at or too close to the first maximum of the graph in this calculation. They obtained a value that lay outside the acceptable range.

(c) The answer that was most commonly given here was *400 MPa*. The second most popular answer was the correct one but it was very noticeably infrequent.

(d) (i) No credit was awarded for the answer *it is stretching* since the stem of the question makes clear that the strain is increasing. Rather more was expected.

(ii) There were some good answers here and credit was awarded for a variety of possible approaches. Answers that made no reference to the microstructure in some way were not infrequent.

(e) Many answers mentioned the area under the graph although a few were less precise and only referred to the area of the graph or even the area without making it clear it related to the graph. Many, but not all, of these answers continued by suggesting that this area be multiplied by the volume of the sample.

Question 3

(a) This was almost always correct with only the candidates who performed less well on the paper as a whole not reaching the correct answer. The value of *g* given in the list of data is $9.81\ \text{N kg}^{-1}$. It is best that candidates use this value.

(b) (i) Again, the correct answer was widely obtained although a few inaccurately rearranged formulas led to the reciprocal of the correct answer being quoted.

(ii) There were many ways of obtaining full credit here and many candidates did. It was unfortunate when a carefully considered answer did not mention whether the temperature difference that would result would be greater or less than the predicted value.

(c) The command word in the question was *Explain*. Many answers did little more than state again that the rate of flow does not affect the temperature difference. Most candidates who obtained full credit, supplied an expression for the change in gravitational potential energy and for the increase in internal energy of the water. They then stated that the mass cancelled out.

Question 4

(a) (i) Electromotive force was very commonly defined correctly. There were answers that did not use the expression *per unit charge* or *per coulomb*; the expression *for a given charge* was not enough for full credit.

(ii) Many answers were fine but this was a question where rather vague and imprecise answers were quite common. Resistance is a measurable quantity with a specific definition and answers that stated that the internal resistance was *the energy lost* or *the voltage decrease* or *a force opposing the current* within the cell were not accepted.

(b) (i) Many candidates gave the correct answer here but some gave an answer that was equal to the difference between the electromotive force and the correct answer (that is *the lost volts*). This was often obtained by multiplying the wrong resistance by the correct current.

(ii) This was often awarded full credit either because the correct answer was calculated or through the use of the error carried forward process. Errors did arise, however, when the wrong potential difference or the wrong resistance value was used.

(c) (i) These two parts were quite commonly correct and only very occasionally were the correct responses reversed. The single most significant source of forfeited credit was for answers that stated the laws with no reference to the principles of physics of which they are a consequence.

(ii)1. Many candidates were able to determine the correct equation although several different confusions arose. The term $0.90i$ was often omitted from the equation and the electromotive force of the two cells was often given as 2 × 1.29 (V) rather than as 2 × 1.52 (V) or 3.04 (V).

2. Those who obtained the correct equation in the previous part often solved it and determined the current in the cell. Those whose previous equation did not include a term in *i* were only rarely able to make any progress here.

Question 5

(a) (i)(ii) These two parts were similar calculations and many candidates obtained full credit for two correct speeds. There were candidates who calculated the first speed correctly but who then used an incorrect refractive index (1.54/1.33 in some cases) in the second part.

(b) (i) Most candidates found this part relatively straightforward and were awarded full credit. The most common source of in accuracy was to use the angle supplied 25.0° as the angle of incidence rather than its complement. Some candidates used 75.0°.

(ii) The ray in the glass and the ray in the water were frequently drawn in an acceptable manner and full credit was often awarded. A small number of candidates who performed well on the rest of the paper, left this part unanswered.

(iii)1. Most candidates gained some credit here with full credit being awarded quite regularly. Candidates who used the refractive index of glass in air were in the minority but were usually awarded partial credit.

2. This part proved very challenging and some candidates did not know how to proceed. There were candidates who wrote that total internal reflection can never occur when light passes from an optically denser into an optically rarer medium; this, of course, is not the case. Some of the candidates who performed well over all produced some very impressive algebra that showed succinctly and clearly why the statement in the question was correct.

Question 6

(a) This most common answer given was the correct one. An answer of half the correct value was also seen quite commonly but this was often obtained from an attempt to apply the formula for double slit interference to this situation.

(b) (i) Although reference was very frequently made to destructive interference, it was not always clear what was interfering with what. General answers such as *This is due to constructive and destructive interference*, needed to be more detailed and to be related to the context of the question asked.

(ii) This was often correct and full credit was awarded quite frequently.

(iii) This part also attracted answers of a very general form and again imprecise references to destructive interference were made. Many answers seemed to suggest that the light from a single slit was somehow interfering with light from the double slit. Only occasionally did a candidate recognise that the missing fringes were the result of there being no light at such a location due to the effect of single slit diffraction.

Question 7

(a) The equation was almost always awarded full credit although there was a small number of candidates who exchanged the *0* and the *–1* in the nuclide notation for a beta-particle. There were also a few candidates who struggled to subtract –1 from 28.

(b) (i) This was mostly answered correctly although some candidates used rather vague terms such as *the amount of decay per second*. A few responses suggested that the candidate made no distinction between the activity of a sample and the count-rate registered on a nearby ratemeter.

(ii) The answers here ranged from full credit to no credit although many candidates did make some reference to exponential decay. The question required an explanation for the shape of the graph and the candidates who addressed this carefully were those who gained full credit here.

(c) A majority of candidates stated that the temperature of the sample did not affect its activity although there were also many who stated that the activity at a lower temperature would be smaller. The explanation was usually restricted to quoting the fact that radioactive decay is spontaneous and very commonly random was also included. Perhaps such candidates are unsure about the distinction between the two terms.

Question 8

(a) This was almost universally correct although one or two candidates only made reference to the colour of the light.

(b) (i) The frequency calculations were usually conducted accurately although the graphs that were plotted varied somewhat in standard. A few candidates used axes that were the wrong way around and some points were inaccurately plotted. Candidates should not use scales that lead to awkward calculations in order to locate each point. In this case, a scale of 0.15 V to 2.0 cm was not at all easy to use or helpful.

There are several quantities that can be deduced from the graph and a few candidates calculated the values of all of these. Other candidates wrote quite extensively but were awarded little credit as what was written was too general or not particularly related to what could be deduced. There was a wide range of credit awarded here.

(ii) 1. Most candidates realised what was expected although answers such as *The energy is not enough* were not sufficiently exact.

2. Only a few candidates realised what this essentially practical point was concerned with.

Question 9

(a) There was a range of answers here with some giving the expected answer whilst others gave answers that were too imprecise or made no reference to energy.

(b) (i) This was another question where the credit awarded varied widely; full credit was quite commonly gained as was no credit at all. The two relevant values of *E* were calculated in a variety of ways. Functions such as lg (4.06), ln (4.06), lg (4.84 – 4.06), $10^{(4.84 - 4.06)}$ and also the correct versions were often seen and candidates attempted to manipulate the numbers from the graph There were several stages to the calculation and some candidates omitted some of these.

(ii) 1. This part was often well answered although the exact order of events was not always clear.

2. Most answers were awarded some credit and many were awarded full credit. The most common omission was not to state that the energy of the emitted photon was greater for K_β. There were some candidates who stated that a shorter wavelength corresponded to a lesser photon energy.

3. The diagrams were rarely well drawn and several needed to be present for full credit to be awarded. Almost every combination of correct and incorrect versions of these features were seen somewhere.

(iii) 1. Only a few candidates gave a clear description of what needed to be done. Many of those who suggested that a graph needed to be plotted did not then state how the graph should be interpreted or how it could show the validity of the relationship. Other referred to the constant of proportionality in an equation without mentioning what equation was being referred to. Credit was forfeited by candidates whose answers were imprecise and unclear.

2. Many answers were awarded some credit but few gained full credit. The command word *Explain* was often neglected.

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

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

(iii) Many candidates produced answers that suggested some understanding of what was being asked for. The point that the intensity of the image on an X-ray picture indicates the types of material at the corresponding location was not always made clearly or explicitly.

(d) This was usually well answered and full or almost full credit was frequently awarded.

PHYSICS

Paper 9792/03
Paper 3 Written Paper

General comments

Most if not all candidates seemed to have sufficient time to finish the paper and all marks were accessible.

Once again the majority of candidates selected the first three optional questions (**Questions 7**, **8** and **9**) but good answers were seen to all six questions in ***section 2***. The strategy adopted in this section seemed to be centre dependent, with **Question 10** being popular for candidates from some centres (and often well answered) and yet tackled by no candidates at all from some other centres. It was also apparent that candidates from some centres only tackled three questions in ***section 2*** whereas candidates from other centres tried (in whole or in part) four or more questions. In some cases where more than three questions in ***section 2*** were attempted the results on two or more of the responses were unimpressive, suggesting that these candidates tended to start a question and then move on to another one when they got stuck, in the hope that they could do better on the additional question. Since there was little evidence of candidates running out of time it might be advisable to encourage candidates to spend a little time reading carefully through all of the questions in ***section 2*** before making their choice of which three to answer and then to answer them fully.

Whilst there were many good mathematical answers these were often completely unexplained (and in some cases poorly presented) so that when something went wrong it was hard to give credit for working. Written answers to commands such as ‘state’, ‘explain’ or ‘suggest’ were often the weakest part of a candidate’s work, and precise physics terminology was not always used. In many cases a bullet point approach might have served some candidates better than simply filling the available space with unfocused paragraphs.

Comments on specific questions

Question 1

Parts **(b)**, **(c)(i)** and **(c)(iii)** were usually done well although some candidates omitted the sign in **(c)(i)** and others were careless over significant figures.

Whilst many candidates knew Kepler’s laws, a significant number failed to state them fully and common errors were: to state that the Sun was at the centre of the elliptical orbit; not to mention focus or foci; to state that the planet sweeps out equal areas in equal times without referring to the line from the planet to the Sun; to quote r^3 proportional to T^2 with no indication of what r or T represent.

Question 2

This was generally answered well with many excellent responses, but some candidates tried to use the equations from the formula list rather than equations derived from the actual variation of displacement and so confused sines and cosines in **(b)(ii)**. Other common errors were to confuse f and ω or to take the mass as 4.31 kg.

Part **(c)(ii)** proved challenging, with many giving the answer 2 000 Hz. The small number of candidates who did get the correct answer here had often worked it out by drawing a higher frequency wave onto the diagram.

Question 3

Parts **(a)(i)** and **(a)(ii)** and **(b)(i)** were generally well done but **(b)(ii)** proved challenging. Many candidates ignored the information in the question and simply quoted a result or derivation using *B*, *v* and *d* without relating it to the situation presented.

There were very few good answers to **(b)(iii)** and even among those who realised that the lower Hall voltage was a result of lower drift velocity (for the same current) they often incorrectly attributed this to ‘high resistance or resistivity’ of copper.

Question 4

This question was answered well by the majority of candidates and many were able to score full marks.

Question 5

Parts **(a)(i)** and **(a)(ii)** were usually answered well although a significant number of candidates gave only half of the minimum angle because they had used half the baseline (i.e., radius rather than diameter of orbit).

Part **(a)(iii)** proved challenging with many unclear, rambling, or confused responses. Some candidates may well have done better to think about key points and to list them as bullet points rather than write a paragraph that often contained very few pieces of relevant physics.

In **(b)(i)** most candidates were able to calculate the temperature. Some interpreted λ_{max} as the maximum value on the scale i.e. 10 ($\times 10^{-7}$) giving 2900K.

For **(b)(ii)** there were many good answers, but quite a few were unable to calculate the luminosity, having not remembered the inverse square law formula. There were some careless arithmetical errors.

Question 6

This question, in common with others that required careful explanations, was often poorly answered.

In part **(a)** many candidates did not refer to experimental evidence and simply described an energy level model of the atom. Some who realised that emission or absorption spectra provided evidence did not state that these have discrete frequencies corresponding to discrete energies or if they did they related the energy of the photons directly to energy levels inside the atom instead of to transitions between energy levels.

(b)(i) was answered correctly by the majority of candidates and only a few made significant figure or sign errors.

(b)(ii) was poorly answered by a large number of candidates. One of the most common errors was to treat the hydrogen atom as if there is an electron occupying every level and then to consider which of these can be ‘knocked out’. Some candidates who realised that the only possible excitation is to n = 2 did not include the possibility of an elastic collision with no excitation.

Section 2

Questions 7, 8 and 9 are the optional questions with a mathematical focus.

Question 7

This was generally well answered with a significant number of the higher performing candidates gaining full or near to full marks. However, there was a minority of candidates who struggled to score any of the 6 marks available in part **(a)** with a common error being to make the resultant force tangential rather than centripetal. Some failed to label any of the drawn forces.

Part **(b)** was a standard derivation and was generally well done. However, a significant number of candidates seemed to remember the general form of the derivation but did not actually define their terms clearly and yet somehow almost magically arrived at the correct answer. A very common error was to leave out or misdefine the surface density or to use density incorrectly when finding δm and yet to cancel this error when substituting back for total mass at the end.

(c)(i) proved challenging for some, and triangular graphs were quite common. Some of those who drew the correct basic shape paid little attention to the gradient (which should have been zero) at the start and end points.

In **(c)(ii)** a significant number used an incorrect value for the average torque or used the maximum value of 0.0060 N m.

(c) (iii) was generally well done even if it involved an error carried forward from **(c)(ii)**.

Question 8

There were some very good answers to this question with a significant number scoring high marks.

Many candidates made no attempt to explain what they were doing in **(a)(i)** so the link to randomness was not present and they could not score either mark.

(a)(ii) was well done, more frequently by integrating the equation rather than by the simpler method of differentiating the solution.

(b)(i) Was fine and most got these marks.

(b)(ii) graph plotting etc… was usually good, but a significant number of candidates used a simple decay graph rather than the required ln/linear graph, and some of the latter then used one half-life rather than working from the gradient and its connection to λ.

Few candidates gained both marks for **(c)(i)**. A significant number thought that the binding energy was present in the bonds or somehow holds the nucleus together and some referred only to atoms. Those who stated that it was equal to the work done to separate nucleons often missed the point that they must be separated to 'infinity' or at least until they are no longer interacting. It was not uncommon to see contradictions where a candidate claimed that the binding energy was both the energy needed to hold the nucleus together and to break it apart.

(c)(ii) Most candidates knew how to start this and began to calculate a mass difference. However, some made arithmetic errors, some got confused by units, bringing in factors of c^2 etc… and some calculated the total binding energy rather than binding energy per nucleon, so it was only a minority who gained 3 marks here.

(c)(iii) This is a graph that candidates are expected to be familiar with, only a minority were and few placed the peak in the correct position relative to values on both axes.

Question 9

This question often proved the hardest for those choosing to answer **Questions 7, 8** and **9**.

The calculations in parts **(a)(ii)** 1 and 3 and **(b)** were generally well done with many candidates gaining all of these marks.

Part **(a)(i)** proved surprisingly challenging, with few candidates knowing how charge is distributed on the plates and a significant number not referring to amount of charge at all.

(c) Proved one of the most challenging questions on the entire paper and very few candidates scored highly on this part. The idea was to apply what they know about capacitors in d.c. circuits to an unfamiliar a.c. context. To do this they needed to use the knowledge that current is rate of change of charge and the basic equations for charge, capacitance and energy. Many of the responses, or lack of a response, suggested that they were not confident in doing this. In **(c)(iii)** many attempts at drawing a sine-squared graph were careless and could not be awarded the mark.

Question 10, 11 and 12 are the optional questions on philosophical issues.

Question 10

There were some good answers to this question but the distribution of attempts amongst centres suggested that this topic is perhaps not tackled by all centres or that candidates are being steered away from it.

(a) was usually answered quite well although often the level of detail was insufficient to gain both marks.

(b)(ii) was often answered in general terms rather than, as the question required, referring back to the results of the experiments.

(c)(i) and **(ii)** were done well although in **(ii)** some simply presented a calculation and did not interpret this in relation to whether or not humans could survive such a journey.

(c)(iii) proved challenging and only a very small proportion of candidates gained full marks on this part. The common mistakes were to think that the time dilation factor had to reduce 42 000 years (or 21 000 years) to 5 years whereas the time from Earth would also be reduced at a higher speed. Candidates who made this mistake did gain partial credit for obtaining a value of v from their equation although many missed the significance of a return journey.

In **(c)(iv)** most candidates could get one mark but did not refer to another moving inertial frame.

(d)(i) was generally answered well although some candidates confused simultaneity with time dilation.

In **(d)(ii)** there were a few clear answers but candidates often lost marks because they did not state what would be expected given absolute time or clarify what they meant by simultaneity (i.e. having two events at different positions being simultaneous in a particular inertial reference frame but not in another inertial reference frame in relative motion). Here and in **(d)(i)** some candidates seemed to think that the relativity of simultaneity referred to events at one position rather than in two separate locations.

Question 11

A smaller number of candidates attempted this than attempted **Question 10** but there were some good answers.

(a)(i) was answered correctly by most candidates.

(a)(ii) was answered correctly by most candidates.

Candidates who had done **(a)(ii)** correctly were usually able to get the mark for **(a)(iii)** too.

In **(a)(iv)** there were some good answers but some candidates did not seem to appreciate what they needed to do to show that relativistic effects could be ignored and not all attempted a calculation.

In **(a)(v)**there were a small number of good answers but the most common error was to answer in very general terms with no reference back to the value calculated in **(a)(iii)**.

(b)(i) was done well by many candidates although some candidates omitted the negative sign.

In **(b)(ii)** a very small number of candidates answered this convincingly. Once again (as with **(a)(v)**) many candidates gave very general answers that did not draw on the information in the question or calculate the uncertainty in kinetic energy of an electron trapped within the nucleus. There were a number of unconvincing arguments based in vague terms on the uncertainty principle for position and momentum.

In part **(c)** there were a few very good answers to this question but some candidates did not focus on physical principles or make clear points. Some answers simply repeated the same point. Once again, it might be worth candidates considering the use of bullet points to answer this kind of question

Question 12

A very small number of candidates attempted this question and in some cases these seemed to have turned to it as a last resort, having tried and failed to answer earlier questions. The style of question requires clear points to be made and reasoned arguments to be presented. Unfortunately, some of the candidates who attempted this question tended to write vaguely and at length without pinning their arguments to clear physical principles.

In **(a)(i)** diffraction effects were only mentioned by a few candidates and these rarely elaborated on the implications for the torch beam (i.e. relationship to wavelength and to diameter of aperture). There were a significant number of answers based on the uncertainty principle and these could have gained more marks if the argument had been developed.

In **(a)(ii)** there were a significant number of answers based on the uncertainty principle, often verbatim from **(a)(i)** and with the same limitations. Some candidates did not refer to photons.

(a)(iii) was answered well by several candidates. The common error was to try to answer entirely in terms of energy transfer with no reference to the second law of thermodynamics or entropy.

In part **(b)(i)** heat transfer to the surroundings was usually identified but latent heat was rarely mentioned.

In **(b)(ii)** the change of entropy was usually identified, but the reason entropy has changed and its link to number of ways was only seen rarely.

b)(iii) proved challenging, and very few candidates gave a convincing response. many simply stated that 10°C was above the freezing point of water, making no reference to the second law or to entropy.

In part **(c)** most candidates who attempted this realised that something happens as *v* approaches *c* and the majority of these showed that mass approaches infinity. Whilst this was identified as a problem it was not always made clear what this implied in terms of a requirement for infinite energy or force and an asymptotic speed of *c*.

PHYSICS

Paper 9792/04
Personal Investigation

General comments

This year there was again a good range of interesting personal investigations. Good candidates clearly enjoy the experience and benefit greatly from the Personal Investigation part of the course. Candidates appear to have been suitably prepared. The majority of centres take a large amount of care with regard to the marking, checking the marking and internally moderating the marking. This is very helpful to the moderation 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.

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.

When moderating the samples of work, 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. It was clear from the moderation process that the majority of centres marked the tasks carefully and it was pleasing to see many helpful annotations. Several centres enclosed annotated copies of the marking criteria whilst several centres produced a rationale for the awarding of the marks. These processes very much assist the moderation process. It is obviously helpful that both good physics and wrong physics in the reports are highlighted to judge the award of the appropriate mark. Centres where there were more than one marker had carried out an appropriate 'internal standardisation' process.

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.

Once again it was clear that centres have approached the Personal Investigations professionally and the overall quality of the investigations has been good. The success of the Personal Investigation is also due to the care and attention to detail of centres both supervising the investigation and carefully assessing the candidates' work.

Comments on specific tasks

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 text book. 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 text book 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 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. 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.

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, it was not always clear as to their reasoning and thus the treatment of uncertainties was in some cases generously allowed. A good number of the more able candidates successfully plotted log-log graphs to test for 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 for 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.

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.