PHYSICS

Paper 9702/11

Multiple Choice

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

In this paper only 2 questions had more than 70% correct answers. These were **Questions 35** and **38**. There did not appear to be any falling off of achievement with **Questions 31** to **40** so there was no indication of candidates running out of time.

Comments on Specific Questions

Questions 1 to **6** were answered reasonably well.

Question 7

This question had 47% correct answers though many candidates did not realise that the horizontal velocity of the ball will also be affected by air resistance. It cannot stay constant over a considerable time but will fall to zero, while the vertical velocity will rise to a constant value. The question states that the ball is affected by air resistance; this cannot be just its vertical motion.

Question 13

Only 28% of candidates answered correctly by performing the calculation, (15 × 3) – (10 × 2) – (5 × 2) = 15 N m. Many candidates must have assumed that the horizontal force provided a clockwise moment and others must have guessed an answer.

Question 15

40% of candidates chose either B or C; diagrams that do not show a resultant force of zero. Another 40% did get the correct answer, D.

Question 16

There seemed to be a good deal of guessing in answering this question, suggesting that candidates may benefit from further support in the subject of thermal physics.

Question 18

Only 23% of candidates could write "$m_1gv = m_2gv$ + answer". The kinetic energy distractor here ignores completely any energy input.

Question 24

This question produced some unnecessarily poor answers. This type of question is very easy to answer correctly by one simple piece of advice – namely "draw the new wave *on the paper* as it will appear a short time later". Candidates are often very reluctant to use the paper itself to write on. With the additional line on the diagram it becomes clear that the correct answer is C. At A the water must be moving downwards – yet 60% of candidates put this as their answer and only 9% gave the correct answer.

Question 25

Candidates often correctly found the factor of 0.5 but forgot to square it for the intensity.

Question 27

Many candidates showed that they are not familiar with the wavelengths of the constituents of the electromagnetic spectrum.

Question 33

Questions such as this ought to be regarded as routine, but candidates still need to work through them carefully. Now that space is being left for working it is essential that candidates use it. For their own benefit they should use words when working things out and not just a string of letters and figures. It is all too easy to make careless mistakes when answers are worked out in one's head.

Question 37

The voltmeter must read 4 V when the slider is at X. When it moves to Y, potentiometer P and the voltmeter are in series with almost all the resistance in the voltmeter, and hence the p.d. across the voltmeter is still 4 V. Only 26% of candidates realised this. About 60% of the candidates thought that B or C was the correct answer.

Question 38

This was well answered with 79% getting the correct answer.

PHYSICS

Paper 9702/12
Multiple Choice

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

Only one question produced more than 90% correct responses but there were several questions where the percentage of correct responses was rather low. Details of these questions will follow in this report.

The time allocation for this paper is very short so any checking of answers needs to be done immediately after obtaining the initial response. It is hoped that by leaving plenty of space for working, candidates would be encouraged to construct their answers in writing rather than by working in their heads.

Questions 30 to **40** were answered as well as other sections of the paper so there was no indication of candidates running out of time.

Comments on Specific Questions

Question 4

This question produced only 53% correct answers. Significant figures are a perpetual problem, especially when zeros are involved, but here three significant figures are clearly necessary.

Question 5

This also resulted in a low proportion correct of 39%. Candidates need to know that with subtraction of data the uncertainty is still added, as arithmetic will show by obtaining highest and lowest possible values for x.

Question 7

This was the first of the questions with an unduly low percentage of correct responses with only 16% correct. Candidates should have been able to eliminate A and B just from the first line of the question. "Positive is upwards": the acceleration due to gravity is therefore negative. At the ceiling the downward acceleration is even larger so D is correct.

Question 8

This was a complex question and it was difficult to find any short cut to the answer. The best way of doing the calculation is to consider the first stage and then both stages together. Then the initial velocity can easily be eliminated.

Question 9

This question ought to have taken a very brief time to answer correctly. A cannot be correct because the particle is still going in the initial direction. In B it stops and in D it must have undergone an elastic (not an inelastic) collision. C, the correct answer was chosen by only 11% of candidates.

Question 13

59% of candidates incorrectly gave B as the answer. The reading of course is not the upthrust but the weight minus the upthrust. The weight is unchanged so D is correct, but only 13% gave this as their answer.

Question 22

Only 23% were able to reach the correct conclusion in this question, perhaps because they assumed that a high spring constant is what is required for large deflection. Here the thinner spring stretches most when the loading is light but it can go no further than the rigid box. The sensitivity falls thereafter. A circular scale on a commercial balance with a similar difference of sensitivity will perhaps have a scale occupying 10 cm for the first 100 g, followed by 40 cm for a total mass of 4 kg.

Question 28

This question had only 32% correct responses, largely because candidates did not appreciate that with an electric field the horizontal velocity remains unchanged but that there will be an increase in speed because of the vertical component of velocity given to the electron.

Questions 31

A large number (40%) thought that electrons were stationary in a wire carrying no current, rather than moving at random.

Question 32

Only 23% realised that it is the work done across the internal resistance that causes the drop in p.d.

Question 34

Many candidates thought that D was the correct response. A bit of extra thought was necessary to see that the answer is B.

Question 40

The last question caused some difficulty. The half-life is uncertain because of randomness of the decay, but A is wrong in any case because the time *interval* between the 424 and 212 readings is 80 minutes and not 90 minutes.

PHYSICS

Paper 9702/13
Multiple Choice

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

The overall standard of the candidates was very encouraging but only 3 questions had 90% or more correct answers. These were **Questions 7, 33** and **39**.

Questions 30 to **40** were answered as well as other sections of the paper so there was no indication of candidates running out of time.

Comments on Specific Questions

Question 2

This produced a rather low 61% correct answers. This is almost certainly not because of the difficulty of the question, but of not considering all the possibilities. Candidates should be encouraged to consider all the options before choosing their answer. Two clear statements need to be written down on the exam paper here. The first needs to be something along the lines of "3000 revolutions in one minute means 50 revolutions in 1 second" and "allowing for 5 pulses takes 0.1 s for the 10 cm across the screen". This gives the answer of 0.01 s for 1 cm. i.e. 10 ms. 39% of candidates were out by at least a factor of 100.

Question 11

This was the question on the whole paper with the lowest percentage of correct answers. The candidates did not realise that the horizontal velocity of the ball will also be affected by air resistance. It cannot stay constant over a considerable time but will fall to zero, while the vertical velocity will rise to a constant value. The question states that the ball is affected by air resistance; this cannot be just its vertical motion.

Question 13

Only 69% of candidates gave the correct answer. 21% of candidates chose either B or C; diagrams that do not show a resultant force of zero.

Question 14

Only half of the candidates were able to write (15 × 3) – (10 × 2) – (5 × 2) = 15 N m in order to obtain the correct answer.

Question 17

44% of candidates give the wrong answer, B. Only 36% of candidates could write "$m_1gv = m_2gv$ + answer". The kinetic energy distractor here ignores completely any energy input.

Question 25

This question produced some unnecessarily poor answers. This type of question is very easy to answer correctly by one simple piece of advice – namely "draw the new wave *on the paper* as it will appear a short time later". Candidates are often very reluctant to use the paper itself to write on. Here it becomes abundantly clear that the correct answer is C. At A the water must be moving downwards, yet 33% of candidates put this as their answer.

Question 35

This was not very well answered because it was somewhat different from other questions of this type. The voltmeter must read 4 V when the slider is at X. When it moves to Y, potentiometer P and the voltmeter are in series with almost all the resistance in the voltmeter, and hence the p.d. across the voltmeter is still 4 V. Only 21% of candidates realised this. More than half the candidates thought that B was the correct answer.

PHYSICS

Paper 9702/21
AS Structured Questions

General comments

There were a few candidates who were well-prepared for the examination. Many candidates did not show the skills necessary for them to be successful.

Candidates need to be encouraged to improve their recall of standard definitions, laws and equations. With this knowledge, candidates can go on to develop the understanding necessary to apply it.

There were many candidates who did not complete their answers to the questions or who left parts of questions completely blank. However, there was no evidence amongst adequately prepared candidates of a shortage of time.

Candidates should be advised not to commence any answer by writing out large portions of the question. This is very wasteful of valuable time.

Comments on Specific Questions

Question 1

Candidates need to learn all the base quantities. They should then be able to express all derived quantities in terms of these base quantities.

(a) A minority of candidates were able to give three SI base quantities. Candidates need to be able to recall all the quantities that are fundamental to this course.

(b)

(i) There were some very poor answers given for the SI base units of force, density and velocity. Some of the answers suggested a lack of understanding of base quantities and derived quantities.

(ii) A minority of candidates were able to check the base units in the equation given for the resistive force and obtain a correct answer.

Question 2

Candidates need to be aware that the horizontal and vertical motion of a projectile in a gravitational field can be analysed in two separate calculations.

(a)

(i) A significant number of candidates realised that the horizontal component of the ball's velocity would remain constant as the ball moved towards the ground. However, very few were then able to use a right-angled triangle to obtain the relationship between the horizontal and vertical components of the velocity at point P.

(ii) The application of an equation for constant acceleration was carried out by some of the well-prepared candidates. The majority of candidates did not use the correct component of velocity or were unable to obtain a solution using a valid equation.

(iii) The majority of candidates were unable to obtain a correct answer for this problem. There were a number of candidates who did not realise that there was no acceleration in the horizontal direction. The intermediate step required a calculation of the time taken to reach point P. This caused difficulty for the majority of candidates.

(b)

(i) This part enabled some of the weaker candidates to score at least partial credit. The majority realised that the ball would reach a greater horizontal distance. However, further credit was often not awarded owing to poor or inaccurate drawing of the curve. Some of the curves were drawn going upwards at the start and some had the angle the curve made with the ground greater than that of the original.

(ii) The majority of candidates were able to score partial credit for a curve that reached the ground before the original. Again further credit was often not awarded owing to poorly drawn curves.

Question 3

(a) A minority of candidates were able to give the standard relationship between force and momentum.

(b)

(i) There were very few correct answers. The main error made by those candidates who knew the correct equation for momentum was to ignore the change in direction of the ball after it made contact with the bar. Other errors made were to mis-read the initial velocity from the graph or to fail to convert the mass into kilograms.

(ii) There were very few correct answers. A solution to this problem depended on the candidates obtaining an answer to **(b)(i)** and knowing the relationship asked for in **(a)**. Only the able and well-prepared candidates completed this part successfully.

(c) There were very few correct answers. A number of candidates attempted to obtain an answer using moments. However, the majority did not take moments about a suitable pivot point and/or did not include the weight of the bar.

Question 4

(a) This part was straightforward and a significant number of candidates were able to give correct expressions for the majority of quantities.

(b)

(i) For the majority of candidates who gave the correct expression in **(a)**, this calculation presented few difficulties. The answer being given in the question helped some candidates from making a power-of-ten error.

(ii) For the majority of candidates, this calculation caused considerable difficulty. Care should always be taken to ensure that, in numerical questions, the values substituted for quantities have consistent units (usually SI units). If the units used are inconsistent then this often leads to a power-of-ten error in the final answer.

(c) Many candidates did not realise that the very small change in resistance was a reason why the method was inappropriate.

Question 5

(a) The well-prepared candidates generally gave a correct description.

(b) In most scripts, candidates appeared to have the correct ideas but frequently the standard of the drawing meant that credit was lost. Candidates should realise that the wavelength should be clearly shown as unchanged after diffraction at the slit.

(c) This straightforward calculation presented a number of difficulties mainly from inconsistent use of SI units. This often led to a power-of-ten error in the final answer.

(d) There were very few correct answers. Only the well-prepared candidates gave a response to this part.

Question 6

(a)

(i) For the majority of candidates, this calculation presented few difficulties.

(ii) The more able candidates completed the graph with few problems. Candidates should be encouraged to include on the axes of a sketch graph the values that are relevant to any data that is provided or calculated in the question.

(b) There were very few correct answers. All three calculations proved to be difficult for most candidates. The calculation of the power dissipation in resistors when the resistors are connected across a power supply in straightforward parallel or series combinations was found to be particularly difficult.

Question 7

(a) The attention of candidates should be drawn to the distinction between atom, nucleus, nucleon and nuclide. In this question, it is nuclei that have the same number of protons that should be used to explain isotopes.

(b)

(i) Very few candidates were able to give more than one correct quantity that is conserved in a nuclear reaction.

(ii) Very few candidates were able to apply the conservation laws to the nuclear equation and obtain the correct values.

PHYSICS

Paper 9702/22

AS Structured Questions

General comments

There were some candidates who gave excellent answers to questions and were, quite clearly, well-prepared for the examination. There were many other candidates who did not show the skills necessary for them to be successful.

Candidates need to be encouraged to improve their recall of standard definitions, laws and equations. With this knowledge, candidates can go on to develop the understanding necessary to apply it.

There were few candidates who did not complete their answers to the questions. There was no evidence amongst adequately prepared candidates of a shortage of time.

Candidates should be encouraged to read the questions carefully. Candidates should also be advised not to commence any answer by writing out large portions of the question. This is very wasteful of valuable time.

Comments on Specific Questions

Question 1

This proved to be a good introductory question with many candidates scoring full credit in **(a)**.

(a)

(i) The majority of candidates distinguished clearly between vector and scalar quantities. A small minority of candidates concentrated on the requirement of a direction for a vector quantity and omitted the need for a magnitude to describe both quantities.

(ii) Most answers were correct. A few candidates incorrectly considered temperature or electrical resistance to be vector quantities.

(b) A large number of candidates obtained the correct answer for the tension. The majority of candidates attempted the question by calculation. The most common successful answer resolved the forces in a direction parallel to the slope. Some candidates attempted to resolve vertically and horizontally but few completed the long calculation successfully. Very few used a scale diagram. Those who did draw a scale diagram tended to draw a very small vector triangle which was often of the wrong shape.

Question 2

Candidates need to be aware that the horizontal and vertical motion of a projectile in a gravitational field can be analysed in two separate calculations.

(a)

(i) The majority of candidates gained partial credit for resolving the velocity correctly. However, a significant number of candidates did not use the horizontal component of velocity in their calculation or assumed that there was an acceleration due to gravity in the horizontal direction.

(ii) The answers to this part were generally poor. Many candidates tried to link the vertical distance travelled to the horizontal distance by using simple trigonometry. Candidates often did not use the vertical component of the velocity or used a positive value for the acceleration. A significant number of candidates did not read the question carefully. Many made the assumption that the ball had reached maximum height as it reached the wall and used maximum range and height formulae.

(b) The vast majority of candidates were able to draw an acceptable path for the ball between point P and the wall. However, the path drawn for the ball after hitting the wall was frequently incorrect with the ball leaving the wall at an inappropriate angle. There was a large number of candidates who ignored the instruction to sketch the path of the ball on Fig. 2.1 and drew their own version instead. Hence comparison with the original path was difficult and as a result many candidates could not be awarded credit. Candidates should be advised to follow the instructions given in the question.

Question 3

(a) The vast majority of candidates gave a correct answer. A minority did not make their answer clear with a description that stated ‘it is where the weight acts’ rather than the point where the weight appears to act.

(b) A large majority of candidates were able to mark and label the correct position for the centre of gravity. However, the arrow representing the weight was often drawn towards the bottom corner of the card and therefore at an angle to the vertical.

(c)

(i) The well-prepared candidate gave the correct description of friction but the normal reaction force from the rod was not described as well. There were many answers that suggested that the question had not been read carefully. A significant number of candidates gave the weight or the force provided by the hand as the forces that act on the card.

(ii) The more able candidates stated the correct answer with the centre of gravity vertically below the rod. Very few candidates went on to explain that the weight did not produce a moment when the card was in this position. The majority explained the general conditions for equilibrium but did not apply this to the problem in the question. The weaker candidates did not answer the question. There was no statement of the position of the card when it comes to rest. The answer given appeared to try and explain why the card came to rest.

Question 4

(a) The majority of candidates scored at least partial credit. The marking points that were often not awarded were a result of a lack of a full explanation. In ‘show that’ questions where the answer is given, candidates should be made aware that a full explanation is required for credit to be awarded. All terms must be stated explicitly and all stages of the derivation must be clearly stated. Many candidates referred to Hooke’s law without stating the law. The majority of candidates did not explain where the factor of a half came from in their derivation.

(b)

(i) The majority of candidates gave the correct answer.

(ii) The majority of candidates realised that the strain energy was determined by calculating an area on the graph. However, the calculations were often made assuming that the lines on the graph were straight. The difference between the areas of two triangles was a common answer.

(iii) Candidates should be encouraged to read the questions carefully. Many answers were based on a change in the dimensions of the wire or simply a statement that plastic deformation had occurred. Very few candidates realised that the change in structure was due to a rearrangement of the atoms.

Question 5

The question was generally well answered and produced good differentiation. Well-prepared candidates scored very highly and weak candidates were able to obtain some of the credit available.

(a)

(i) The majority of answers were correct. Some candidates did not state that the distance was from the rest position but stated it was from a start or the original position. Some candidates gave the explanation in terms of the distance moved in a specific direction. This did not answer the question that asked for the definition with reference to wave motion.

(ii) The majority of the answers were correct. Some candidates stated that the wavelength was the distance between crests/troughs or particles with the same phase. The answer required that this was the 'minimum' distance.

(b) The majority of candidates scored partial credit on this part of the question.

(c)

(i) The correct explanation was generally given. The weaker candidates used displacement instead of amplitude in their explanation and therefore did not score any credit.

(ii) The well-prepared candidate scored full credit. However, some candidates mis-read the amplitude on the graph at 6.0 cm. Others did not work out a final value but left their answer as a ratio of two numbers and so were not awarded credit. The weaker candidates did not use the relation between intensity and amplitude squared.

Question 6

Candidates should be advised to read the questions carefully. In this question this applies to the circuit diagram as well as the text.

(a)

(i) Many of the more able candidates calculated the resistance between the points A and B correctly. There were some candidates who then went on to calculate the total resistance of the circuit. This was not asked for.

(ii) Many candidates seemed to be unaware that the calculation of the total resistance between A and B had simplified the circuit. The calculation of the potential difference across AB should have been straightforward using the potential divider formula or by calculating the circuit current first. Candidates used incorrect combinations of resistance, potential difference and current as well as mixing resistance values in Ω and kΩ. A common error was to consider the 9 V from the supply to be across the 1200 Ω resistor.

(b)

(i) The more able candidates calculated the correct answer. A few candidates went on to calculate the resistance of the thermistor and gave this as their answer. Such candidates need to be advised to read the question carefully. A common error was to use the current calculated in **(a)(ii)**. The candidates who followed this method had not read the question that stated the temperature of the thermistor had changed and hence so had the resistance in the circuit and therefore the current. The more able candidates were able to recover from this error and obtained full credit in **(b)(ii)** with error carried forward being applied.

(ii) A minority of candidates obtained a correct answer. A significant number of candidates assumed that the total resistance between points A and B has a linear relationship with temperature.

(c) There were very few correct answers. Answers tended to be vague without any application of the answers obtained in the question or any reference to the problems of this arrangement.

Question 7

(a) The majority of the candidates did not state the result that was the relevant evidence for the two conclusions given in the question. The answers given suggested that the candidates had not read the questions carefully. Often all the evidence was given in **(a)(i)** or the structure of the atom was described in detail. Many of the answers that did attempt to give the required evidence did not gain any credit because the statements given were not comparative. The use of 'some', 'a small number', 'many' or 'large number' was not accepted. The answers that were required included such statements as 'a small proportion', 'most' or 'the majority'.

(b) There were very few answers that achieved full credit. Many candidates stated different properties of β-particles without considering whether they were relevant to the context of the question.

PHYSICS

Paper 9702/23
A2 Structured Questions

General comments

There were some candidates who gave excellent answers to questions and were, quite clearly, well-prepared for the examination. There were many other candidates who did not have the skills necessary for them to be successful.

Candidates need to be encouraged to improve their recall of standard definitions, laws and equations. With this knowledge, candidates can go on to develop the understanding necessary to apply it.

There were fewer candidates who did not complete their answers to the questions. There was no evidence amongst adequately prepared candidates of a shortage of time.

Candidates should be advised not to commence any answer by writing out large portions of the question. This is very wasteful of valuable time.

Comments on Specific Questions

Question 1

A minority of candidates gave acceptable estimates for all three quantities. Candidates should be encouraged to consider the magnitudes of quantities, especially when they are carrying out practical work. Some answers did indicate a lack of appreciation of the situations. For example, in **(b)**, estimates varied from minutes to nanoseconds and in **(c)**, from 10^{-3} N to 10^{6} N.

Question 2

Candidates should be encouraged to read the questions carefully. Many answers were based on properties of the materials rather than the structures.

Reference was frequently made to regular arrangements or lattices or long chains without stating what components would make up these structures.

There were few comprehensive statements for amorphous solids. It was not appreciated that there is a disordered arrangement of atoms/molecules and, if there is any ordering, then it is short-range.

Question 3

Answers were, in general, disappointing. Candidates were expected to state that the microphone/loudspeaker is connected to the Y-plates of the c.r.o. Some indication of the adjustment of the c.r.o. was expected along with the measurements made. The formula for the calculation of the frequency should be given.

Candidates should be encouraged to draw diagrams that indicate the necessary information and not rough sketches that lack accuracy. All too often, the c.r.o. was shown as a box with one lead from a microphone going to an unlabelled point on the box. The waveform drawn frequently had varying amplitude and distance for one cycle.

The use of a c.r.o. in a laboratory situation should be encouraged.

Question 4

(a) With few exceptions, candidates drew an acceptable line using a straight edge.

(b) In general, it was realised that the diameter of the ball was involved. The nature of this involvement was not always made clear.

(c)

(i) Apart from those answers where the scale had been read incorrectly, a value for the diameter was given within acceptable limits.

(ii) The vast majority of answers did involve the calculation of a gradient. The attention of candidates should be drawn to the fact that, when determining a gradient, the co-ordinates of two widely separated points on the line should be used. All too often, one point was used, thus assuming the line passes through the origin.

A common misconception was to assume that the gradient of the line is the acceleration.

Question 5

(a) Most answers were correct.

(b) The majority of answers referred to zero kinetic energy initially with maximum kinetic energy at the lowest point. Candidates should be encouraged to read the question carefully. They were told that, at the lowest point, the mass temporarily comes to rest and thus the kinetic energy must be zero at this point.

(c)

(i) For the majority of candidates, this calculation presented few difficulties. Care should always be taken to ensure that, in numerical questions, the values substituted for quantities have consistent units (usually SI units). If the units used are inconsistent then this often leads to a power-of-ten error in the final answer.

(ii) In some scripts, the answer was obtained, quite correctly, using proportionality. The most common approach was to determine a value for the spring constant and then to substitute into the expression $E = ½kx^2$. As in **(c)(i)**, attention should be drawn to the correct use of units to prevent a power-of-ten error.

Question 6

(a) In general, the principle was known well. The attention of candidates should be drawn to the fact that displacements are added, not amplitudes. Furthermore, the wording of the question should not be repeated in the answer. In this instance, nothing is added to the answer by stating that 'the waves superpose'.

(b)

(i) This straightforward calculation presented very few difficulties apart from that inconsistent use of SI units often led to a power-of-ten error in the final answer.

(ii) **1.** There were very few correct answers. The most common response was zero phase difference despite being told that a dark fringe is formed.

2. Most answers did involve the correct relation between intensity and amplitude. There were few calculations where the amplitudes were added for the bright fringe and subtracted for the dark fringe. Most answers indicated amplitudes of 2 units and of 1.4 units for the bright and the dark fringes respectively.

Question 7

(a)

(i) In most scripts, candidates appeared to have the correct ideas, but frequently the standard of the drawing meant that credit was lost. Candidates should realise that the path between the plates is a curve, starting and ending level with the edges of the plates. Also, the path beyond the plates is straight and is a tangent to the curve.

(ii) It was common to find that an expression for t was given as v/L or was misunderstood.

(b)

(i) Most definitions were acceptable. Reference should always be made to total momentum and that the principle applies only to a closed system.

(ii) Despite being told to use the answers in **(a)(ii)**, many attempts involved the product of m and v.

(iii) There were some very good answers. Most candidates did make a reference to the fact that the particle is not an isolated system in that an electric force acts on it.

Question 8

(a)

(i) This task was completed successfully by most candidates and adequate explanation was given.

(ii) The formula for resistivity was given correctly in most scripts. Where candidates are asked to derive a given numerical answer then they should give a clear explanation. In this instance, a factor of 2 appeared all too frequently without any explanation in order to arrive at the given answer.

(b) This calculation proved to be difficult for most candidates. A correct approach was to calculate the current using the combined resistance of the heater and the cable. Then the power of the heater could be found using the resistance of the heater. Very frequently, the total power dissipated in the heater and the cable was determined.

(c) There were many incomplete answers. Candidates should be advised to state carefully where any additional power is dissipated when two or more components are involved.

Question 9

(a) The attention of candidates should be drawn to the distinction between atom, nucleus, nucleon and nuclide. In this question, it is the nucleus that emits either α- or β- and/or γ-radiation to form either a different or a more stable nucleus. Furthermore, there is a common misconception that the α- or β- and/or γ-radiations are radioactive.

(b) Parts **(i)** and **(ii)** were answered well. In **(iii)**, most candidates did realise that the source must be an α-emitter. Common misconceptions were either that the α-particles must combine with β-particles to form helium atoms or that the α-particles are helium atoms.

PHYSICS

Paper 9702/31
Advanced Practical Skills 1

General comments

The general standard of the work done by the candidates was good, similar to last year.

The majority of Centres had no problem in providing the equipment required for use by candidates. Any deviation between the requested equipment and that provided to the candidate **must** be written down in the Supervisor's Report and CIE should be notified so that the Examiners can take this into consideration during the marking period. Experiments are designed with the view that Centres will have the apparatus as outlined in the syllabus available for use.

Any help given to the candidate should be noted on the Supervisor's Report. Supervisors are reminded that under **no circumstances** should help be given with the recording of results, graphical work or analysis.

Candidates did not seem to be short of time and both questions were attempted by most candidates. Candidates were confident in the generation and handling of data. Candidates are more confident with the critical evaluation of the experiment under investigation and this can be further improved upon. There are a number of Centres where the candidates can improve their written answers. Specific examples include: stating the read-offs used for the gradient calculation; showing the substitution used for the calculation for the *y*-intercept where there is a false origin; and showing the percentage ratio calculation needed to find the percentage uncertainty instead of only writing a bald number on the answer line without any working.

There were no common misinterpretations of the rubric.

Comments on Specific Questions

Successful collection of data

Question 1

(a)

(i) Many candidates were able to set up the circuit without help from the Supervisor. Candidates should be encouraged to ask for help in the setting up of the practical if this enables them access to the credit in the rest of the question.

(ii) Many candidates stated values of *a* and *b* to the nearest mm with a consistent unit. Candidates can gain full credit by ensuring they read the ruler to the nearest small division i.e. to the nearest mm.

(b) Most candidates scored full credit for taking six sets of readings of *R*, *a* and *b* to give the correct trend. Candidates need to take <u>six</u> sets of readings to gain full credit. If a candidate has provided seven sets of readings then they can still gain full credit for taking readings and must transfer *all* tabulated readings onto the graph to access full credit on the graph (unless a candidate chooses to cross out one tabulated result).

Range and distribution of marks

(b) Many candidates gained full credit by extending *R* to include either the 7000 or 8000 Ω resistor. Other candidates need to maximise their range to enable a better quality of results.

Presentation of data and observations

Table

(b) Many candidates gained credit for correct column headings. Other candidates need to include a distinguishing mark between the quantity and the unit where appropriate (*R*/Ω), mindful that the column heading *b*/*a* requires no unit in order to gain full credit for column headings. All the raw values of *a* and *b* should be given to the same number of decimal places. Some candidates need to state their values of *a* and *b* to the nearest mm in order to gain credit. Most candidates gave their significant figures in the calculated quantity *b*/*a* taking into account the number of significant figures used in the raw values of *a* and *b*. The majority of candidates calculated *b*/*a* correctly.

Graph

(c)

(i) Candidates were required to plot a graph of *b*/*a* against *R*. Many candidates gained credit for drawing appropriate axes. Other candidates need to check their scales as there were missing numbers along the scale (e.g. 1000, 2000, 3000, 5000, 6000 along the *x*-axis) or gaps in the scale which were bigger than three large squares or missing labels. Other candidates can improve by checking that the first and last plot extend over at least six squares in the *y*-direction and four squares in the *x*-direction and checking that all the plots can fit on the graph grid provided.

Many candidates gained credit for plotting tabulated readings. Candidates need to draw plotted points so that their diameter is equal to or less than half a small square. Other candidates can gain full credit by plotting the points to the nearest half a small square.

(ii) Many candidates were able to draw an acceptable line of best fit through five or six trend points. Other candidates need to rotate their lines to give a better fit or move their lines to give a better balance of points about the line. Candidates need to draw a line of best fit that best represents all of their data and not choose a few points that go through the line or, as is commonly seen, choosing the first and the last point to fit on the line.

Analysis, conclusions and evaluation

Interpretation of graph

(iii) Many candidates used a suitably large triangle to calculate a negative gradient, gaining credit for their read-offs and substitution into $\Delta y/\Delta x$ to find the gradient. Other candidates need to check that the read-offs used are within half a small square of the best fit line drawn, show their substitution clearly into $\Delta y/\Delta x$ and not $\Delta x/\Delta y$, and check that their triangle is large enough (the hypotenuse should be at least half the length of the line drawn) in order to gain credit.

Most candidates read off the *y*-intercept at $x = 0$ successfully gaining credit. Other candidates substituted into $y=mx+c$ successfully to determine the *y*-intercept gaining credit. Some candidates used values from the table or graph that were off the line of best fit, and instead need to use points from the line of best fit. Other candidates needed to check that the origin started with $x = 0$ before reading off the *y*-intercept from the graph.

Drawing conclusions

(d) Many candidates were able to give the values of *X* using the correct method i.e. gradient = $1/X$ with the gradient value taken from **(c)(iii)** gaining full credit. Other candidates, in order to improve, should use the value they have worked out for the gradient instead of substituting new plots into the equation to solve for *X*. Many candidates gave an answer close to the unknown value of the resistor gaining credit. Other candidates needed to include a consistent unit in order to gain full credit.

(e) Many candidates gave the correct read off from the graph for when $b/a = 1$.

Question 2

In this question candidates were required to investigate how the motion of two masses connected by a string passing over a pulley depends on the difference between the two masses.

Successful collection of data

(c)

(i) Many candidates were able to set up the experiment without help stating h to the nearest mm gaining full credit. Candidates can gain full credit by ensuring they write a consistent unit and state their reading to the smallest division on the ruler provided, that is mm.

(d)

(ii) Most candidates were able to measure m_A and m_B and work out $m_A – m_B$ correctly gaining full credit.

(iii) Most candidates recorded a time with a consistent unit and repeated their measurements to gain full credit for this section. Candidates can improve upon their answers by showing evidence that times have been repeated and that the times stated have been read correctly from the stopwatch (e.g. 3.03 seconds instead of 3.03 mins).

(f) Most candidates were able to measure a second t, m_A and m_B and work out $m_A – m_B$ correctly gaining full credit for this section.

Quality

(f) Most candidates found that t for the larger difference in masses was smaller.

Display of calculation and reasoning

(g)

(i) Many candidates were able to calculate k for the two sets of data, showing their working and gaining full credit. Some candidates need to remember to square the t term in the equation for k in order to gain full credit.

(ii) A minority of candidates related the significant figures for k to the significant figures in all the raw values of t and $m_A – m_B$ (or m_A and m_B) used in calculating k, gaining full credit for this section. Most candidates need to state these quantities and then link the number of significant figures in the experimental data to the number of significant figures used in k in order to gain credit.

Analysis, conclusions and evaluation

(iii) A minority of candidates compared their values of k using a percentage difference and linked this to a judgement of whether or not their results supported the given relationship, by comparing this percentage difference with an experimental percentage error either taken from **(e)** or estimated themselves. Candidates are encouraged to work out the percentage difference between the two k values and then make a judgement whether this is above or below what is expected for this particular experiment. Candidates are encouraged to state what they think is a sensible limit for the percentage uncertainty for this particular experiment.

Estimating uncertainties in *t*

(e) Most candidates stated the correct ratio idea (×100) for working out the percentage uncertainty gaining credit. Most candidates were able to consider a realistic uncertainty in the time measurement in order to gain full credit for this section.

Evaluation

(h) Many candidates scored at least partial credit in this section and the quality of written answers has improved. Candidates are now more likely to look at the experiment and state what problems they had and offer some solutions. The key to this section is for candidates to identify real problems associated with setting up this experiment and in obtaining the readings (e.g. difficulty in releasing mass, holding the ruler and starting the timer at the same time) and come up with detailed practical solutions that either improve the technique or give more reliable data. For example 'the masses hit each other so use a larger pulley' gains credit for one problem and one solution. Candidates can improve their written answers by stating the methods used for each solution. In doing this, candidates look at how each solution helps this particular experiment (e.g. fix the retort stand to the bench using clamps). Candidates are encouraged to steer away from what they should already be doing throughout the experiment (e.g. reading the height in such a way so as to avoid parallax error, repeating readings in *t*).

PHYSICS

Paper 9702/33
Advanced Practical Skills 1

General comments

The general standard of the work done by the candidates was good, similar to last year.

The majority of Centres had no problem in providing the equipment required for use by the candidates. Any deviation between the requested equipment and that provided to the candidate **must** be written down in the Supervisor's Report and CIE should be notified so that the Examiners can take this into consideration during the marking period. Experiments are designed with the view that Centres will have the apparatus as outlined in the syllabus available for use.

Any help given to the candidate should be noted on the Supervisor's Report. Supervisors are reminded that under **no circumstances** should help be given with the recording of results, graphical work or analysis.

Candidates did not seem to be short of time and both questions were attempted by most candidates. Candidates were confident in the generation and handling of data. Candidates are more confident with the critical evaluation of the experiment under investigation and this can be further improved upon. There are a number of Centres where the candidates can improve their written answers. Specific examples include: stating the read-offs used for the gradient calculation; showing the substitution used for the calculation for the *y*-intercept where there is a false origin; and showing the percentage ratio calculation needed to find the percentage uncertainty instead of only writing a bald number on the answer line without any working.

There were no common misinterpretations of the rubric.

Comments on Specific Questions

Question 1

In this question candidates were required to investigate how the motion of a pendulum bob is affected by the height of the bob above the bench.

Successful collection of data

(a)

(ii) Many candidates gave their values of *h* to the nearest mm. Candidates can gain full credit by ensuring they write their measurement to the smallest division on the ruler provided (mm), and give a consistent unit.

(b) Many candidates repeated multiple swings, averaged the time taken and divided by the number of swings to get *T* below 3 seconds gaining full credit. Also gaining full credit were candidates who timed several single swings and averaged the answer to give *T*. Some candidates gave answers much bigger than 3 seconds suggesting that the candidates needed to divide by the number of swings taken to gain full credit.

(c) Most candidates scored full credit for taking six sets of readings of *x* and *T* to give the correct trend. Candidates need to take <u>six</u> sets of readings to gain full credit. If a candidate has provided seven sets of readings then they can still gain full credit for taking readings and must transfer *all* tabulated readings onto the graph for access to full credit on the graph (unless a candidate chooses to cross out one tabulated result).

Range and distribution of marks

(c) Many candidates gained full credit by extending *x* to include a value equal to or above half the height of the suspended bob in **(a)(ii)**. Many candidates needed to increase the range of *x* taken to gain credit here: for example, some candidates went up from 5 cm in 1 cm intervals to 11 cm, when intervals of 5 cm or 10 cm would give access to a better quality of results.

Presentation of data and observations

Table

(c) Many candidates gained credit for correct column headings. Other candidates need to include a distinguishing mark between the quantity and the unit (T^2/s^2) to gain full credit for column headings. All the raw values of *x* should be given to the same number of decimal places as well as the values of *T*. Some candidates need to state their values of *x* to the nearest mm to gain credit. The majority of candidates gave their significant figures in the calculated quantity T^2 taking into account the number of significant figures used in the raw values of time. The majority of candidates calculated T^2 correctly.

Graph

(d)

(i) Candidates were required to plot a graph of T^2 against *x*. Many candidates gained credit for drawing appropriate axes. Other candidates need to check their scales as there were missing numbers along the scale (e.g. 1,2,3,5,6,7 along the *x*-axis) or gaps in the scale which were bigger than three large squares or missing labels. Other candidates can improve by checking that the first and last plot extend over at least six squares in the *y*-direction and four squares in the *x*-direction, and checking that all the plots can fit on the graph grid provided.

Many candidates gained credit for plotting tabulated readings. Other candidates need to draw plotted points so that their diameter is equal to or less than half a small square, whilst other candidates can gain full credit by plotting the points to the nearest half a small square.

(ii) Many candidates were able to draw an acceptable line of best fit through five or six trend points. Other candidates need to rotate their lines to give a better fit or move their lines to give a better balance of points about the line. Candidates need to draw a line of best fit that best represents all of their data and not choose a few points that go through the line or, as is commonly seen, choosing the first and the last point to fit on the line.

Analysis, conclusions and evaluation

Interpretation of graph

(iii) Many candidates used a suitably large triangle to calculate a negative gradient gaining credit for their read-offs and substitution into $\Delta y/\Delta x$ to find the gradient. Other candidates need to check that the read-offs used are within half a small square of the best fit line drawn, show their substitution clearly into $\Delta y/\Delta x$ and not $\Delta x/\Delta y$ and check that their triangle is large enough (the hypotenuse should be at least half the length of the line drawn) in order to gain credit.

Some candidates read off the *y*-intercept at $x = 0$ successfully gaining credit. Many candidates substituted into $y=mx+c$ successfully to determine the *y*-intercept gaining credit. Some used values from the table or graph that were off the line of best fit, and instead need to use points from the line of best fit. Other candidates need to check that the origin started with $x = 0$ before reading off the *y*-intercept from the graph.

Drawing conclusions

(e) Many candidates were able to give the values of *A* and *B* using the correct method: gradient = –*B* and *y*-intercept = *A* with gradient and intercept values taken from **(d)(iii),** gaining full credit. Other candidates, in order to improve, should use the values they have worked out for the gradient and the *y*-intercept instead of substituting new plots into the equation to solve for *A* and *B.*

Many candidates gave an answer close to their value of *h*, gaining full credit for careful practical work. Other candidates needed to include a consistent unit in order to gain full credit.

Question 2

In this question candidates were required to investigate how the potential difference across a current-carrying wire depends on its diameter.

Successful collection of data

(a) Some candidates measured diameter *d* using a micrometer screw gauge to the nearest 0.01 mm, repeating their readings gaining full credit. Other candidates needed to give consistent units in order to gain credit, for example 0.27 mm instead of 2.70 cm, or repeat their readings, or read the micrometer screwguage correctly (e.g. 0.27 mm instead of 0.77 mm).

(c)

(i) Many candidates were able to measure *L* to the nearest mm gaining full credit.

(d)

(ii) Most candidates successfully recorded a voltage.

(e) Most candidates recorded a second value of *d*. Weaker candidates should be encouraged to ask for help setting up the circuit so that they can gain credit for readings taken.

(f)

(ii) Most candidates recorded a second voltage with correct units.

Quality

(f)

(ii) Most candidates found that the voltage for the larger diameter wire was smaller. In some cases when the second voltage was greater than the first, the candidates had apparently used the wires in the wrong order.

Presentation of data and observations

Display of calculation and reasoning

(g)

(i) Many candidates were able to calculate *k* for the two sets of data showing their working and gaining full credit. Some candidates need to remember to square the *d* term in the equation for *k* in order to gain full credit.

(ii) A minority of candidates related the significant figures for *k* to the significant figures in all the raw values of *V*, *d* and *L* used in calculating *k* gaining full credit for this section. Most candidates need to state these quantities and then link the number of significant figures in the experimental data to the number of significant figures used in *k* in order to gain credit.

Analysis, conclusions and evaluation

(iii) A minority of candidates compared their values of *k* using a percentage difference and then linked this to a judgement of whether or not their results supported the given relationship, by comparing this percentage difference with an experimental percentage error either taken from **(c)(ii)** or estimated themselves. Candidates are encouraged to work out the percentage difference between the two *k* values and then make a judgement whether this is above or below what is expected for this particular experiment. Candidates are encouraged to state what they think is a sensible limit for the percentage uncertainty for this particular experiment.

Estimating uncertainties in *L*

(c)

(ii) Most candidates stated the correct ratio idea (×100) for working out the percentage uncertainty gaining credit. Many candidates need to consider a realistic uncertainty in the length measurement given that the wire is bent and not necessarily an easy measurement to take (i.e. 2–10 mm) in order to gain full credit for this section. Although the smallest division on the rules used was 1 mm, it was not reasonable to expect that the length of a bent wire which was not fixed could be measured to this precision.

Evaluation

(h) Many candidates scored at least partial credit in this section and the quality of written answers has improved. Candidates are now more likely to look at the experiment and state what problems they had and offer some solutions. The key to this section is for candidates to identify real problems associated with setting up this experiment (e.g. difficult to measure length <u>because</u> the clips slip along the wire) and in obtaining the readings, and come up with detailed practical solutions that either improve technique or give more reliable data. For example 'the wire was bent so fix the wire with tape' gains credit for one problem and one solution. Candidates can improve their written answers by stating the methods used for each solution. In doing this candidates look at how each solution helps this particular experiment (e.g. fix the wire <u>using</u> clamps). Candidates are encouraged to steer away from changing the experiment to a different one (e.g. test for different types of wire or different lengths of wire). Candidates are also encouraged to avoid mentioning anything that they should already be doing throughout the experiment (e.g. checking the diameter at different places, reading the analogue meter from above to avoid parallax errors).

PHYSICS

Paper 9702/34

Advanced Practical Skills 2

General comments

The level of difficulty was similar to that of previous years and overall performance was good.

The apparatus arrangement was straightforward in both questions and no Centre reported that candidates had needed help from the Supervisor with setting up. There were few problems with providing the necessary apparatus, although one or two Centres had to use square section plastic bottles for **Question 2**. Centres are reminded that any deviation between the requested equipment and that provided to the candidate **must** be written down in the Supervisor's Report.

Candidates had time to complete both questions and in most cases the instructions were understood and followed carefully. Those from the majority of Centres had been well prepared and were experienced in taking measurements and processing and presenting data, leading to a generally good performance in **Question 1**. The discussion section at the end of **Question 2** produced more variation, with the stronger candidates giving clear and specific answers instead of responses that were too vague.

Comments on Specific Questions

Question 1

In this question candidates were required to investigate the equilibrium of a metre rule balanced on a curved surface.

Successful collection of data

(c) All candidates recorded initial values for the heights above the bench of the unloaded rule. Many gave quite dissimilar values for these heights, indicating that they had missed the instruction to balance the rule so that it was parallel to the bench.

(d) Nearly all candidates successfully recorded six sets of measurements for different numbers of paper clips suspended from the rule.

In a few cases a disruption to the overall trend suggested that the rule had been repositioned on the beaker part way through the experiment. A very small number of candidates chose n=0 for one of their six values, so that the corresponding 1/n value could not be plotted.

h_1 and h_2 were measured using a rule with millimetre divisions and most candidates correctly recorded all their values to the nearest mm (e.g. 12.0 cm), with only a minority wrongly adding an extra zero (e.g. 3.10 cm) to some or all of their values.

Range and distribution of marks

(d) Up to 15 paper clips could have been added to the rule (unless the rule touched the bench before this). The more able candidates considered this carefully and chose a large part of the available range together with sensible intervals between n values.

Presentation of data and observations

Table

(d) Candidates had been well prepared in the presentation of results and tables were generally neat and clear.

The only difficult unit in the headings was that for $1/(h_1–h_2)$ which should have been cm^{-1} but was sometimes omitted or given as cm.

The choice of significant figures for the value of $1/(h_1–h_2)$ was unusual in that it should be based on the s.f. in the difference $(h_1–h_2)$ rather than the s.f. in h_1 and h_2 themselves. Even strong candidates sometimes had difficulty with this.

A few candidates rounded their values of $1/n$ to 1 s.f. (not necessary since n is not a measured value) and this lead to a large apparent scatter when plotted.

Graph

(e) Centres had clearly been taught the necessary skills and standards were generally high, with many candidates gaining full credit.

Most graphs utilised at least half the length of each axis and only a few used awkward scales. It should be easy to read off intermediate values so scale markings should correspond to whole units, e.g. 0.08, 0.10, 0.12 and not 0.083, 0.103, 0.123.

Plotting was usually clear and accurate, with only a few cases of unnecessary rounding of values before plotting (this often lead to points being mis-plotted by more than half a small square).

The choice of best-fit straight line was not always straightforward. In some cases the candidate would have done better to ignore a single stray point when drawing the line instead of giving it undue importance.

Analysis, conclusions and evaluation

Interpretation of graph

(e) Nearly every candidate knew how to find the gradient of the graph, and the only errors were in using too small a triangle or mis-reading coordinates. The y-intercept could not usually be read directly from the graph because of a false origin so most candidates calculated it, usually successfully.

Drawing conclusions

(f) The majority of candidates compared their graph with the equation relating $1/(h_1–h_2)$ and $1/n$ and then correctly equated the constant a with their gradient and the constant b with their intercept. Units for both constants were also required and the stronger candidates inspected the equation to identify cm^{-1} as the unit in both cases.

Question 2

In this question candidates were required to investigate the rate of flow of water through a hole in a plastic bottle.

Successful collection of data

(a) Candidates had been provided with two set squares and a ruler to measure the bottle diameter. Nearly all recorded a sensible value and a very small number gained additional credit for repeating and averaging (a sensible procedure for this type of measurement since the cross section may not have been a precise circle).

(b) The measurements of *x* (the distance between the lines) and *h* (the distance to the base of the bottle) had to be measured using a millimetre scale and weaker candidates made the error of adding an extra zero to their value (e.g. $x = 0.90$ cm).

(d) The time for the water level to fall between the lines was of the order of 10 s and most candidates recorded a sensible value to the nearest 0.1 s or 0.01 s. Some weaker candidates recorded values less than 1 s or greater than 100 s, probably because they mis-read the digital stopwatch. Such candidates may benefit from more practice carrying out experiments involving timing with stopwatches.

Estimating uncertainties

(b)

(ii) The uncertainty in the value of *x* was correctly calculated by most candidates using an absolute uncertainty of 1 mm. Although the others usually used a correct method, they chose an unreasonably small 0.1 mm for their absolute uncertainty and in a very few cases the uncertainty was calculated as a percentage of the whole scale length (30 cm).

Presentation of data and observations

Display of calculation and reasoning

(c) (d) A high standard was evident in all these calculations, with the only error of significance being **(d)**, in the unit for the flowrate *R* (weak candidates either omitted this or gave m^3/s instead of cm^3/s).

(f)

(i) Most candidates calculated the two values of *k* by using their flowrate and depth values correctly.

Conclusions

(f)

(ii) Nearly all candidates knew that they had to compare their two *k* values to come to a conclusion. To gain credit the percentage difference between the two *k* values had to be compared with a tolerance before deciding whether the suggested relationship could be valid. The candidate was expected to state the tolerance (e.g. '20%' or 'the experimental uncertainty in **(b)(ii)**'). Several candidates merely said that 'the two values of *k* are close so the relationship is valid' which was not enough.

Evaluation

(g)

(i) The most successful candidates thought about each of the measurements that was needed and described any problems involved in making that measurement accurately, usually identifying the cause of the problem. For example, in relation to timing, 'it is difficult to see the water level' (because the water is colourless) and 'it is difficult to judge when the level passes the line' (because the level is changing). For example, in relation to *x*, 'the percentage uncertainty is very large' (because a millimetre scale is used). For example, in relation to *d*, 'it is difficult to measure the diameter' (because even a small force deforms the bottle).

Weaker candidates often quoted types of error (parallax, zero error, reaction time) without explaining which of the measurements was affected. (In fact there were no serious problems with parallax in this experiment).

(ii) The more able candidates suggested creditworthy improvements that were often linked to a difficulty and included enough practical detail to make the method clear. For example, 'dye the water' (to make the level clearer). For example, 'use a travelling microscope to measure *x*' (to improve the precision).

Weak candidates suggested the use of video to improve the timing, but did not describe how time could be measured during playback. Suggested improvements involving a procedure that could have been carried out by the candidate without any additional apparatus (e.g. 'repeat the timing and take an average') were not credited.

PHYSICS

Paper 9702/35
Advanced Practical Skills 1

General comments

The general standard of the work done by the candidates was good, similar to last year.

The majority of Centres had no problem in providing the equipment required for use by candidates. Any deviation between the requested equipment and that provided to the candidate **must** be written down in the Supervisor's Report as well as notifying CIE so that the Examiners can take this into consideration during the marking period. Experiments are designed with the view that Centres will have the apparatus as outlined in the syllabus available for use.

Any help given to the candidate should be noted on the Supervisor's Report. Supervisors are reminded that under **no circumstances** should help be given with the recording of results, graphical work or analysis.

Candidates did not seem to be short of time and both questions were attempted. Candidates were confident in the generation and handling of data. Candidates are more confident with the critical evaluation of the experiment under investigation and this can be further improved upon. There are a number of Centres where the candidates can improve their written answers. Specific examples include: stating the read-offs used for the gradient calculation; showing the substitution used for the calculation for the *y*-intercept where there is a false origin; and showing the percentage ratio calculation needed to find the percentage uncertainty instead of only writing a bald number on the answer line without any working.

There were no common misinterpretations of the rubric.

Comments on specific questions

Question 1

In this question candidates were required to determine the resistivity of a metal in the form of a wire.

Successful collection of data

(a)

(i) The majority of candidates were able to use a micrometer to measure the thickness of the wire correctly and recorded their answer to either 0.01 mm or 0.001 mm gaining credit. Other candidates need to read the micrometer screw gauge correctly as an extra 0.5 mm appeared on their answer.

(b)

(iii) Most candidates correctly recorded a value of *x* about half-way along the wire and a value for the current *I* with a consistent unit gaining credit. Other candidates need to give a value of *x* greater than 40 cm to gain credit.

(c) Most candidates were able to set up the circuit correctly and collect values of current for six different values of *x* showing the correct trend (*I* decreasing as *x* increases). Some candidates need to record their current values in mA rather than A otherwise this will lead to power-of-ten errors when calculating the resistivity later in **(e)**.

Range and distribution of marks

(c) Some candidates gave a range in *x* that extends over the wire provided gaining credit. Many candidates need to make full use of the available range of values for *x*, extending below 50 cm in order to gain credit.

Presentation of data and observations

Table

(c) Many candidates gained credit for correct column headings. Other candidates need to provide A^{-1} units for the $1/I$ column instead of A or no units. Most candidates gave the raw values of *x* to the same number of decimal places. Some candidates need to state their values of *x* to the nearest mm to gain credit. The majority of candidates gave their significant figures in the calculated quantity $1/I$ taking into account the number of significant figures used in the raw values of current. The majority of candidates calculated $1/I$ correctly gaining credit.

Graph

(d)

(i) Candidates were required to plot a graph of $1/I$ against *x*. Many candidates gained credit for drawing appropriate axes. Other candidates can improve by checking that the first and last plot extend over at least six squares in the *y*-direction and four squares in the *x*-direction, and checking that all the plots can fit on the graph grid provided.

Many candidates gained credit for plotting tabulated readings. Other candidates need to draw plotted points so that their diameter is equal to or less than half a small square, whilst other candidates can gain full credit by plotting the points to the nearest half a small square.

(ii) Many candidates were able to draw an acceptable line of best fit through five or six trend points. Other candidates need to rotate their lines to give a better fit or move their lines to give a better balance of points about the line. Candidates need to draw a line of best fit that best represents all of their data and not choose a few points that go through the line or, as is commonly seen, choosing the first and the last point to fit on the line. Some candidates drew two short lengths of line (perhaps using a short ruler) and this gave kinks along the line. The line of best fit should be drawn continuously using a long ruler.

Analysis, conclusions and evaluation

Interpretation of graph

(iii) Many candidates used a suitably large triangle to calculate a gradient, gaining credit for their read-offs and substitution into $\Delta y/\Delta x$ to find the gradient. Other candidates need to check that the read-offs used are within half a small square of the best fit line drawn, show their substitution clearly into $\Delta y/\Delta x$ and not $\Delta x/\Delta y$ and check that their triangle is large enough (the hypotenuse should be at least half the length of the line drawn) in order to gain credit.

Some candidates read off the *y*-intercept at $x = 0$ successfully gaining credit. Many candidates substituted into $y=mx+c$ successfully to determine the *y*-intercept gaining credit. Other candidates need to use points that were on the line of best fit and not use values from the table or graph that were off the line of best fit. Other candidates need to check that the origin started with $x = 0$ before reading off the *y*-intercept from the graph.

Drawing conclusions

(e) Most candidates recognised that *M* was the gradient and *N* the intercept value calculated previously, and correctly substituted their values (together with their value for *A*) into the equation given in the question, gaining credit. Candidates need to include a consistent unit in order to gain full credit (Ω m instead of $\Omega\ m^{-1}$). Other candidates need to provide the resistivity in range by using mA in the table or by reading the micrometer reading correctly.

Question 2

In this question candidates were required to investigate the equilibrium of a wooden strip.

Successful collection of data

(a)

(ii) Most candidates successfully measured the distance *x*, giving their answer to the nearest mm with a consistent unit. Other candidates need to read the ruler correctly to the nearest mm by recording the correct distance *x* (and not the distance between the mass A and the nail).

(b)

(iii) Most candidates were able to record a value of θ. Other candidates need to measure the angle to the nearest degree (and not to the nearest 0.1˚) in order to gain credit.

(v) Most candidates recorded the values of *m* and *M* correctly with a consistent unit gaining full credit.

(c) Most candidates recorded a second value of θ, and the new values of *m* and *M* gaining full credit.

Quality

(c) Most candidates found that the second value of θ was greater than the first obtained in **(b)(iii)** gaining credit.

Display of calculation and reasoning

(b)

(vi) The majority of candidates calculated *m*/*M* correctly. Other candidates need to express their answer as a number and not as a fraction in order to gain credit.

(d)

(i) Many candidates were able to calculate *k* for the two sets of data, showing their working and gaining full credit.

(ii) A minority of candidates related the significant figures for *k* to the significant figures in all the raw values of θ, *m* and *M* used in calculating *k*, gaining full credit for this section. Candidates need to state these quantities (instead of cos θ and *m*/*M* or 'raw' data) and then link the number of significant figures in the experimental data to the number of significant figures used in *k* in order to gain credit.

Analysis, conclusions and evaluation

(iii) A minority of candidates compared their values of *k* using a percentage difference and linked this to a judgement of whether or not their results supported the given relationship, by comparing this percentage difference with an experimental percentage error either taken from **(c)(ii)** or estimated themselves. Candidates are encouraged to work out the percentage difference between the two *k* values and then make a judgement whether this is above or below what is expected for this particular experiment. Candidates are encouraged to state what they think is a sensible limit for the percentage uncertainty for this particular experiment.

Estimating uncertainties in θ

(b)

(iv) Most candidates stated the correct ratio idea (×100) for working out the percentage uncertainty, gaining credit. Many candidates need to consider a realistic uncertainty in the angle measurement given that the protractor was hand held and this was not necessarily an easy measurement to take (i.e. 2–10˚) in order to gain full credit for this section. Although the smallest division on the protractor used was 1˚, it was not reasonable to expect that the angle of the string could be measured to this precision, as the protractor was held by hand and there was no vertical reference line.

Evaluation

(e) Many candidates scored at least partial credit in this section and the quality of written answers has improved. Candidates are now more likely to look at the experiment and state what problems they had and offer some solutions. The key to this section is for candidates to identify real problems associated with setting up this experiment and in obtaining readings (e.g. difficulty in judging (by eye) whether the wooden strip was horizontal/parallel to the bench; difficulty of measuring the angle accurately holding a protractor in the hand and without a vertical reference line; friction in the pulley bearing; mass A could slip). Candidates are encouraged to give detailed practical solutions that either improve technique or give more reliable data e.g. clamp the protractor on another stand; use a plumb-line as a vertical reference; oil/lubricate the pulley bearing; tape the string holding mass A to the strip to prevent it slipping. Candidates can improve their written answers by stating the methods used for each solution. In doing this candidates should look at how each solution helps this particular experiment. Candidates are encouraged to avoid changing the experiment to a different one, or mentioning methods that they should already be doing throughout the experiment (e.g. reading the protractor from above to avoid parallax errors).

PHYSICS

Paper 9702/36

Advanced Practical Skills 2

General comments

The performance of candidates was good and generally similar to last year. The usual careful preparation of candidates by many Centres led to a high standard in the skills tested in **Question 1**. Candidates' responses showed that they had been well prepared for the practical work and the efforts that Centres make to provide the correct equipment is greatly appreciated. Scores were usually higher in the first question.

There was variation between candidates, shown particularly in the final section of **Question 2**. Many candidates were able to tackle the final section of this question with more confidence. Weaker answers gave too many general, vague comments.

There appeared to be plenty of time to complete the experiments, and there were no common misinterpretations of the rubric.

Comments on Specific Questions

Question 1

In this question candidates investigated how the equilibrium position of a flat board changed as a mass was hung from different holes on the board.

Successful collection of data

(a) Many good answers showed candidates were able to set up the apparatus for themselves.

(c) Good answers showed the length of the board was measured accurately by candidates.

(e) Good answers had candidates able to use the metre rule to measure the values of *h* and *d*. Weaker answers showed a need to understand that, when provided with a metre rule having scale markings shown in mm, then raw measurements of length should be to the nearest mm e.g. 2.0 cm or 2.1 cm. Candidates should not write 2 cm or 2.00 cm. Often candidates add an extra zero and this should be strongly discouraged.

Range and distribution of readings

(f) Excellent answers used a wide enough range of holes, so that *d* values ranged from at least 3.4 cm to 7.6 cm. Weaker answers showed candidates need extra help in how to look at their experiment to consider the readings needed to cover a wide enough range to gain credit. The quality of the data (judged by the amount of scatter about a straight-line trend on the graph) was good for the majority of candidates showing the good preparation Centres had given. Weaker answers again showed candidates will need support to increase their patience and accuracy when taking readings.

Presentation of data and observations

Table

(f) The majority of Centres have done well in teaching candidates how to present their raw readings clearly, in a well drawn table. Headings normally included suitable units. In weaker answers the unit of θ presented a challenge where the heading was written as θ rather than the correct representation of θ/°. Weaker answers showed candidates did not realise that tan θ and therefore 1/tan θ had no unit. Good answers showed careful, correct calculations. Weaker answers were characterised by poor calculation skill in finding 1/tan θ.

The readings of *h* were normally recorded to the same number of decimal places, i.e. to the nearest mm. Weak answers showed extra zeros recorded. Candidates with good answers performed well with significant figures. With significant figures, weak answers showed candidates had not linked the s.f. in the difference between the two heights to the s.f. of 1/tan θ.

Graph

(g) The standard of graph work was usually high, reflecting again the good preparation done in Centres. Good answers showed candidates choosing to use scales based on, for example 2, 4, 5 or 10, with plots spread over more than half the graph grid. Weaker answers were characterised by awkward scales based on 3, 6 or some other awkward number, a scale where one of the plots lay off the printed grid, or with plots compressed into a small portion of the graph grid. Although Examiners expect at least half the grid to be used in both directions, scales should enable intermediate points on the line to be read directly (without having to use a calculator).

Plotting was usually accurate, though weak answers had plots which were penalised for using very large dots (bigger than 1 mm diameter).

Analysis, conclusions and evaluation

Interpretation of graph

(g) In the best responses, candidates had been well prepared for finding the gradient and intercept of a straight line graph. The points chosen for the triangle were clearly shown using points on the line. Candidates accurately read off the plot values and used these correctly, clearly showing their working, before writing the calculated value on the answer line. The intercept was correctly calculated by substituting read offs, from a point which lay on the line, into the equation $y = mx + c$. Alternatively candidates looked carefully to see if their x-axis included the value $x = 0$, if so the intercept could be directly read off from the graph.

Weak answers for the gradient used points on the line which were too close together. A triangle whose hypotenuse was less than half the length of the drawn line did not gain credit in the method of finding the gradient. Weak answers chose values from the table, which did not lie on the line drawn by the candidate. Weaker answers also incorrectly found $\Delta x/\Delta y$ or left the answer as a fraction rather than calculating a final value.

Weak responses in finding the *y*-intercept chose to extend the line below the grid trying to estimate a read off, an inaccurate method which did not gain credit. In some weak answers candidates tried to read off the intercept, but did not notice they had used a point where the *x* value did not equal zero, i.e. a false origin, and rather the read-off just happened to be at the start of the grid.

Drawing conclusions

(h) Many strong answers showed that candidates understood that their values of gradient and intercept calculated in **(g)** corresponded to the values of *a* and *b*, and these values were entered on the correct answer lines, without any further calculations (i.e. candidates had <u>used</u> their answers from **(g)(iii)** of the question, as directed). Weak responses showed new calculations (often using simultaneous equations), not using the previous values of gradient and intercept. Recalculation did not gain credit.

The best answers included the correct units of *a* and did not give a unit for *b*. Weak answers showed it was a struggle to find the units with either no attempt made to give units or giving units involving degrees. This suggests that some candidates need help in how to work out the units of the constants using the equation.

Question 2

In this question candidates were asked to investigate the frictional force between strips of paper, as the area on which a mass rests is changed. The experiment required care and patience on the part of the candidate. Good responses showed excellent preparation by Centres and the ability of candidates to rise to the challenge of the experiment. The best answers showed candidates who diligently wrote down repeat readings taken from the newton-meter then, whilst performing the experiment, thought about why it was difficult to take accurate readings. Thinking about difficulties during the experiment made answering the final section much more straight-forward.

Successful collection and presentation of data

(b)

(i) There were many excellent answers, where candidates were successfully able to measure the length and width of the eraser, recording values to the nearest mm and correctly calculating the area, giving the area in mm^2. Other weaker answers gave lengths as whole cm or added an extra zero e.g. 3.00 cm or gave the unit of area incorrectly as cm. Some weak responses actually measured the depth of the eraser; careful examination of the diagram may have prevented this error.

(ii) Many good answers considering significant figures were spoiled by candidates referring broadly to 'raw data'. Candidates need to understand that specific reference must be made to the quantities that are being measured in their experiment. Here the significant figures in the length and width of the eraser are relevant. Weak answers showed a misunderstanding of significant figures and often mentioned decimal places which did not gain credit.

(d)

(i) The best answers showed repeat readings clearly noted, with the average calculated and the correct unit of newtons given on the answer line. Weaker answers were characterised by a single value, with no repeat values shown, the unit omitted or the meter misread and values greater than 10 N given.

(e) Most answers showed measurements with a correct calculation and repeated force readings.

Estimating uncertainties

(d)

(ii) Good answers showed candidates had noticed that the question asked for the uncertainty which had a unit of N. Weaker responses calculated a percentage uncertainty.

Display of calculation and reasoning

(f) The best answers showed careful thought and compared the difference in the average force for the two different eraser areas with the uncertainty in the force, using their value from **(d)(ii)**, as directed in the question. Weaker answers used ideas relevant to previous papers where a constant or percentage uncertainty had been found, or did not refer to their value from **(d)(ii)**.

Analysis and conclusions and evaluation

(g) It was pleasing to see that candidates from many Centres had been taught how to look at the experiments to find relevant limitations and to make useful suggestions for improvements. The best answers were characterised by suggestions specific to the experiment they had done, thinking about the readings from the newton-meter and the measurements of the erasers. Weaker answers were characterised by general ideas which were too vague such as 'use a digital newton-meter' or 'a better ruler'.

The best answers looked at the force measurement, considering why it was difficult, with words such as “it was difficult to measure the maximum force because the maximum value was only shown for a short time”. Weaker answers stopped at “it was difficult to measure the force” which was not enough to gain credit. Some weak answers noted that the difficulty was linked to “parallax error”. As the candidate performed the experiment, with good practice, they had time to position their head above the scale so reducing parallax. It is assumed that candidates take this sort of precaution naturally. Similarly problems with zero errors were addressed in the best answers at the point where the readings were taken, so should not feature in the limitations section. Weaker answers were distracted by the idea that some mechanical device could provide a constant force, but the idea of the constant force was not helpful, since the force reading rose to a maximum at the point where the paper slid out.

In the best answers the improvement for the above limitation was correctly given as “use a video camera to record the newton-meter reading, playing back to note the value of the maximum force.” Weaker answers talked about “high speed cameras” or “slow motion cameras” or “video the experiment” with no specific reference to measuring the force or using playback.

Many good answers were characterised by including the suggestion that “too few readings were taken”. The improvement given in good answers was “take more readings with a wider variety of areas and plot a graph”. Weaker responses had “take more readings” which could have the meaning of more “repeats”. (It is expected that, with good practice, candidates automatically take and record their repeat readings). Also weak responses did not mention plotting a graph.

Following consideration of the force, good answers transferred their attention to the other measurements made during the experiment, i.e. the length and width of the eraser. Good answers pointed out that the eraser had an irregular shape and included the improvement that vernier callipers be used. Weaker answers included a statement such as “get regular shaped erasers”.

Many candidates realised that the position of the eraser may affect the force values. Excellent answers gave a detailed improvement clearly decribing how a pencil could mark the top piece of paper. Weaker answers stated “mark the paper”.

In thinking about the alignment of the meter and the direction of the force used, good answers suggested the improvement of “drawing a line along which the newton-meter could be pulled”. Weaker answers suggested “pull straight”.

Good answers showed candidates able to pull gently without tearing the paper or deforming the clip. Weaker answers reflected an experiment where the meter was pulled roughly and too hard; this led to distractions where suggested improvements were to use stronger clips or plastic instead of paper.

PHYSICS

Paper 9702/41

A2 Structured Questions

General comments

The majority of candidates found this paper to be challenging. Many candidates seemed to have difficulty demonstrating knowledge and understanding of the basic physics. This was apparent from answers that ignored fundamental principles of physics.

Many candidates had difficulty in calculating numerical values. Frequently, the method and substitution were correct but the final answer demonstrated a lack of calculator skills. Candidates should be encouraged to consider whether any answer is physically reasonable, rather than just accepting a calculator answer as being correct.

The sketching of graphs and diagrams presents difficulty to many candidates. Candidates should be advised to refer to the *glossary of terms* in the syllabus document. Sketches should always give a clear exposition of important details.

Candidates appeared to have sufficient time to complete their answers to the questions. There were comparatively few scripts where parts of questions had been left unanswered.

Comments on Specific Questions

Section A

Question 1

(a) The majority of definitions were satisfactory, with the ratio made clear. Candidates should be advised not to give definitions in terms of units.

(b) Free-hand sketches often did not indicate the important features. Some curves were not smooth. In order for credit to be given, the curve needed to be smooth and to indicate clearly the inverse-square relationship between field strength and distance.

(c)

(i) Answers indicating that the fields due to the Earth and the Moon are equal and opposite were in a minority. Most answers merely made reference to equal field strengths, without considering directions.

(ii) In most scripts, it was realised that the two fields could be equated. There were serious difficulties with regard to the substitution. In many instances, it was not appreciated that, if the distance from the Earth to the point is x, then the distance from the Moon to the point is $(60R_E – x)$.

(iii) It was expected that a smooth curve would be drawn, crossing the axis close to the surface of the Moon. The fields would be in opposite directions with that of the Earth being the greater of the two. In practice, most curves were poorly drawn and did not show relevant features. Candidates should be encouraged to practice the sketching of curves so as to provide the required information.

Question 2

(a)

(i) In most answers, reference was made to forces. Candidates should be advised that 'intermolecular forces' does mean 'forces between molecules'.

(ii) Although reference was usually made to kinetic and potential energies of atoms/molecules, there were comparatively few mentions of 'random distribution'. Candidates should be aware of the difference between ordered kinetic energy of the molecules and kinetic energy due to random motion.

(iii) In some scripts, no mention was made of the fact that the potential energy between the atoms/molecules of an ideal gas is zero. Candidates should be advised to read the questions carefully. In this instance, many stated that rise in internal energy is related to temperature rise and then argued that this temperature rise would increase the kinetic energy of the atoms. Candidates were, of course, expected to commence with a statement relating increase of kinetic energy of atoms to temperature rise.

(b)

(i) Most candidates did realise that, in a complete cycle, the change in internal energy is zero.

(ii) The most common problem in this calculation was concerned with powers-of-ten.

(iii) In general, changes P→Q and Q→R were shown correctly. Despite having answered **(b)(i)** correctly, it was usual to find that the values for the change in internal energy did not add up to zero.

Question 3

(a)

(i) With very few exceptions, the phenomenon was recognised as being that of resonance.

(ii) The majority of answers were correct but a significant number of candidates gave the amplitude as 11 mm and the frequency as 4.3 Hz.

(b)

(i) This calculation was done well by those candidates who were familiar with the phenomenon of simple harmonic motion. Candidates should be encouraged to practice answering such questions.

(ii) The most serious problem was, once again, powers-of-ten.

(c) The quality of the sketches meant that comparatively straightforward work could not be given credit. It was expected that a smooth curve would be drawn with an amplitude always less than that shown. The peak would be flatter and either at the same peak frequency or slightly lower. Most curves were not below that shown and had a sharper peak.

Question 4

(a) Some definitions were, quite rightly, expressed as the ratio of charge to potential. Candidates should be advised that a general definition should not be given in terms of a specific example. In this case, definitions frequently referred to a parallel plate capacitor.

(b)

(i) Where candidates do not write down the constant $4\pi\varepsilon_0$ but instead use the constant k, then the constant k should be explained fully.

(ii) Candidates need to be reminded that, where the command word of a question is *show*, then full explanation is required, including a statement as to which quantities are constants. In this instance, candidates were content to derive an algebraic expression without any accompanying explanation.

(c) Apart from power-of-ten errors, both calculations in this section presented few difficulties.

(d)

(i) It had to be understood that the charge would remain constant. For those who appreciated this fact, the calculation was simple.

(ii) A basic equation for energy was quoted correctly in most scripts. There were many errors when calculating the initial and the final energies in that it was not understood as to what would remain constant. Frequently, the capacitance was not changed. In this example, a simple approach is to use the expression $\Delta E = ½Q\Delta V$.

Question 5

(a) Where a direction is to be described, then candidates should appreciate that an unambiguous term should be used. Many answers included the term *downwards*, without any further amplification.

(b) The calculation was completed successfully by many candidates. However, explanation was often lacking. Candidates should appreciate that this situation is not an equilibrium situation. There is a resultant magnetic force that provides the centripetal force.

(c)

(i) As in previous questions, the quality of sketches was frequently below the standard required. The path should be a semicircle with a diameter greater than 12.8 cm. In many sketches, the beam quite rightly entered the magnetic field at the same position but left the field at the centre of the detector.

(ii) There were many correct answers but, in general, a full substitution was made into the basic formula. Candidates should be encouraged to use proportions, where appropriate. This not only saves time but is less prone to calculator error.

Question 6

(a)

(i) Most answers were based on the fact that soft iron can be 'easily magnetised and demagnetised'. The improvement of flux linkage was not appreciated.

(ii) Candidates should state clearly why and where the e.m.f. is induced, where the eddy currents are formed and where the eddy currents cause heating. Candidates should appreciate that full credit will not be awarded for a mere statement that there is eddy current heating.

(b)

(i) In general, statements were vague. Many involved 'constant current being equal to alternating current'.

(ii) The need for explanation in such questions cannot be stressed too highly. Many candidates received little credit because their work was merely a list of algebraic expressions without even an explanation of symbols.

Question 7

(a) The answers expected were *electron diffraction* (not merely 'diffraction') and *the photoelectric effect*.

(b)

(i) Candidates giving the correct number were in a minority. The most common answer was 'four'.

(ii) Most answers did include a quote of the expression for the energy of a photon but, in many scripts, an incorrect value for the energy change was used.

Question 8

(a) Candidates need to appreciate the difference between the terms *atom, nucleus, nucleon* and *nuclide.* In nuclear fission, it is a 'heavy' nucleus that forms two 'lighter' nuclei of approximately the same mass.

(b) Candidates should be advised not to use an upper case N as the symbol for the neutron.

(c) There were very few explanations where the candidate demonstrated any real understanding of the situation. Most explanations were based on the notion that the neutrons would give off 'heat and light' when they are absorbed in the boron rods. Seldom was any reference made to the nuclear equation in **(b)**. Candidates did not appreciate that the lithium nucleus and the α-particle would have kinetic energy and that this would be transferred in the rods.

Section B

Question 9

(a)

(i) There was much confusion as to whether the amplifier is of the non-inverting or the inverting type.

(ii) The confusion in **(i)** spread to answers for the gain. Candidates should be encouraged to improve their knowledge of this topic.

(b)

(i) In general, the formula stated in **(a)** was used correctly in order to determine V_{OUT}.

(ii) It was quite normal to see answers where the output was greater than 9 V. Candidates need to appreciate what is meant by saturation in the context of an amplifier.

Question 10

(a)

(i) Of those candidates who defined acoustic impedance as the product ρc, most could state what is meant by ρ but many referred to c as merely 'speed'. A minority thought that c is the speed of light.

(ii) The calculation presented very few problems.

(b)

(i) Most answers were correct although a significant minority gave the answer $I = I_T/I_R$.

(ii) Most answers were correct.

(c) Many candidates limited their answers to a statement that the gel would reduce reflection at the skin and thus were only awarded partial credit. The relative intensities for both transmission and reflection should have been considered. Furthermore, most answers considered only ultrasound entering the body and not returning to the transducer.

Question 11

(a)

(i) Reference should be made to unwanted or random signal power. A minority considered noise to be unwanted sound waves.

(ii) In general, *attenuation* was described satisfactorily.

(b)

(i) Most attempts did include a correct formula for power in dB and there were some clearly explained correct solutions. A common error was to assume that the noise power would be amplified between the receiver and the microphone. This then gave a signal-to-noise ratio at the microphone.

(ii) The most common answer was to use repeater amplifiers along the length of the wire pair. Candidates did not seem to realise that this would amplify not only the signal but also the noise. Others suggested using an optic fibre.

Question 12

(a) Many candidates did not read the question carefully and instead described geostationary orbits. Surprisingly, it was not uncommon to find that candidates did not realise that the signal has to be amplified greatly at the satellite although they made reference to change of frequency to avoid swamping of the up-link signal.

(b) Ideas were frequently muddled with many thinking that polar satellites are confined to use near the poles. The need for tracking was mentioned by many but its real purpose was not clearly stated.

The shorter time delay between transmission and receipt of a signal using a polar satellite was frequently misinterpreted as meaning that the transmission would take a shorter time.

PHYSICS

Paper 9702/42

A2 Structured Questions

General comments

The majority of candidates found this paper to be challenging. Many candidates seemed to have difficulty demonstrating knowledge and understanding of the basic physics. This was apparent from answers that ignored fundamental principles of physics.

Many candidates had difficulty in calculating numerical values. Frequently, the method and substitution were correct but the final answer demonstrated a lack of calculator skills. Candidates should be encouraged to consider whether any answer is physically reasonable, rather than just accepting a calculator answer as being correct.

The sketching of graphs and diagrams presents difficulty to many candidates. Candidates should be advised to refer to the *glossary of terms* in the syllabus document. Sketches should always give a clear exposition of important details.

Candidates appeared to have sufficient time to complete their answers to the questions. There were comparatively few scripts where parts of questions had been left unanswered.

Comments on Specific Questions

Section A

Question 1

(a) The majority of definitions were satisfactory, with the ratio made clear. Candidates should be advised not to give definitions in terms of units.

(b) Free-hand sketches often did not indicate the important features. Some curves were not smooth. In order for credit to be given, the curve needed to be smooth and to indicate clearly the inverse-square relationship between field strength and distance.

(c)

(i) Answers indicating that the fields due to the Earth and the Moon are equal and opposite were in a minority. Most answers merely made reference to equal field strengths, without considering directions.

(ii) In most scripts, it was realised that the two fields could be equated. There were serious difficulties with regard to the substitution. In many instances, it was not appreciated that, if the distance from the Earth to the point is x, then the distance from the Moon to the point is $(60R_E – x)$.

(iii) It was expected that a smooth curve would be drawn, crossing the axis close to the surface of the Moon. The fields would be in opposite directions with that of the Earth being the greater of the two. In practice, most curves were poorly drawn and did not show relevant features. Candidates should be encouraged to practice the sketching of curves so as to provide the required information.

Question 2

(a)

(i) In most answers, reference was made to forces. Candidates should be advised that 'intermolecular forces' does mean 'forces between molecules'.

(ii) Although reference was usually made to kinetic and potential energies of atoms/molecules, there were comparatively few mentions of 'random distribution'. Candidates should be aware of the difference between ordered kinetic energy of the molecules and kinetic energy due to random motion.

(iii) In some scripts, no mention was made of the fact that the potential energy between the atoms/molecules of an ideal gas is zero. Candidates should be advised to read the questions carefully. In this instance, many stated that rise in internal energy is related to temperature rise and then argued that this temperature rise would increase the kinetic energy of the atoms. Candidates were, of course, expected to commence with a statement relating increase of kinetic energy of atoms to temperature rise.

(b)

(i) Most candidates did realise that, in a complete cycle, the change in internal energy is zero.

(ii) The most common problem in this calculation was concerned with powers-of-ten.

(iii) In general, changes P→Q and Q→R were shown correctly. Despite having answered **(b)(i)** correctly, it was usual to find that the values for the change in internal energy did not add up to zero.

Question 3

(a)

(i) With very few exceptions, the phenomenon was recognised as being that of resonance.

(ii) The majority of answers were correct but a significant number of candidates gave the amplitude as 11 mm and the frequency as 4.3 Hz.

(b)

(i) This calculation was done well by those candidates who were familiar with the phenomenon of simple harmonic motion. Candidates should be encouraged to practice answering such questions.

(ii) The most serious problem was, once again, powers-of-ten.

(c) The quality of the sketches meant that comparatively straightforward work could not be given credit. It was expected that a smooth curve would be drawn with an amplitude always less than that shown. The peak would be flatter and either at the same peak frequency or slightly lower. Most curves were not below that shown and had a sharper peak.

Question 4

(a) Some definitions were, quite rightly, expressed as the ratio of charge to potential. Candidates should be advised that a general definition should not be given in terms of a specific example. In this case, definitions frequently referred to a parallel plate capacitor.

(b)

(i) Where candidates do not write down the constant $4\pi\varepsilon_0$ but instead use the constant k, then the constant k should be explained fully.

(ii) Candidates need to be reminded that, where the command word of a question is *show*, then full explanation is required, including a statement as to which quantities are constants. In this instance, candidates were content to derive an algebraic expression without any accompanying explanation.

(c) Apart from power-of-ten errors, both calculations in this section presented few difficulties.

(d)

(i) It had to be understood that the charge would remain constant. For those who appreciated this fact, the calculation was simple.

(ii) A basic equation for energy was quoted correctly in most scripts. There were many errors when calculating the initial and the final energies in that it was not understood as to what would remain constant. Frequently, the capacitance was not changed. In this example, a simple approach is to use the expression $\Delta E = ½Q\Delta V$.

Question 5

(a) Where a direction is to be described, then candidates should appreciate that an unambiguous term should be used. Many answers included the term *downwards*, without any further amplification.

(b) The calculation was completed successfully by many candidates. However, explanation was often lacking. Candidates should appreciate that this situation is not an equilibrium situation. There is a resultant magnetic force that provides the centripetal force.

(c)

(i) As in previous questions, the quality of sketches was frequently below the standard required. The path should be a semicircle with a diameter greater than 12.8 cm. In many sketches, the beam quite rightly entered the magnetic field at the same position but left the field at the centre of the detector.

(ii) There were many correct answers but, in general, a full substitution was made into the basic formula. Candidates should be encouraged to use proportions, where appropriate. This not only saves time but is less prone to calculator error.

Question 6

(a)

(i) Most answers were based on the fact that soft iron can be 'easily magnetised and demagnetised'. The improvement of flux linkage was not appreciated.

(ii) Candidates should state clearly why and where the e.m.f. is induced, where the eddy currents are formed and where the eddy currents cause heating. Candidates should appreciate that full credit will not be awarded for a mere statement that there is eddy current heating.

(b)

(i) In general, statements were vague. Many involved 'constant current being equal to alternating current'.

(ii) The need for explanation in such questions cannot be stressed too highly. Many candidates received little credit because their work was merely a list of algebraic expressions without even an explanation of symbols.

Question 7

(a) The answers expected were *electron diffraction* (not merely 'diffraction') and *the photoelectric effect*.

(b)

(i) Candidates giving the correct number were in a minority. The most common answer was 'four'.

(ii) Most answers did include a quote of the expression for the energy of a photon but, in many scripts, an incorrect value for the energy change was used.

Question 8

(a) Candidates need to appreciate the difference between the terms *atom, nucleus, nucleon* and *nuclide.* In nuclear fission, it is a 'heavy' nucleus that forms two 'lighter' nuclei of approximately the same mass.

(b) Candidates should be advised not to use an upper case N as the symbol for the neutron.

(c) There were very few explanations where the candidate demonstrated any real understanding of the situation. Most explanations were based on the notion that the neutrons would give off 'heat and light' when they are absorbed in the boron rods. Seldom was any reference made to the nuclear equation in **(b)**. Candidates did not appreciate that the lithium nucleus and the α-particle would have kinetic energy and that this would be transferred in the rods.

Section B

Question 9

(a)

(i) There was much confusion as to whether the amplifier is of the non-inverting or the inverting type.

(ii) The confusion in **(i)** spread to answers for the gain. Candidates should be encouraged to improve their knowledge of this topic.

(b)

(i) In general, the formula stated in **(a)** was used correctly in order to determine V_{OUT}.

(ii) It was quite normal to see answers where the output was greater than 9 V. Candidates need to appreciate what is meant by saturation in the context of an amplifier.

Question 10

(a)

(i) Of those candidates who defined acoustic impedance as the product ρc, most could state what is meant by ρ but many referred to c as merely 'speed'. A minority thought that c is the speed of light.

(ii) The calculation presented very few problems.

(b)

(i) Most answers were correct although a significant minority gave the answer $I = I_T/I_R$.

(ii) Most answers were correct.

(c) Many candidates limited their answers to a statement that the gel would reduce reflection at the skin and thus were only awarded partial credit. The relative intensities for both transmission and reflection should have been considered. Furthermore, most answers considered only ultrasound entering the body and not returning to the transducer.

Question 11

(a)

(i) Reference should be made to unwanted or random signal power. A minority considered noise to be unwanted sound waves.

(ii) In general, *attenuation* was described satisfactorily.

(b)

(i) Most attempts did include a correct formula for power in dB and there were some clearly explained correct solutions. A common error was to assume that the noise power would be amplified between the receiver and the microphone. This then gave a signal-to-noise ratio at the microphone.

(ii) The most common answer was to use repeater amplifiers along the length of the wire pair. Candidates did not seem to realise that this would amplify not only the signal but also the noise. Others suggested using an optic fibre.

Question 12

(a) Many candidates did not read the question carefully and instead described geostationary orbits. Surprisingly, it was not uncommon to find that candidates did not realise that the signal has to be amplified greatly at the satellite although they made reference to change of frequency to avoid swamping of the up-link signal.

(b) Ideas were frequently muddled with many thinking that polar satellites are confined to use near the poles. The need for tracking was mentioned by many but its real purpose was not clearly stated.

The shorter time delay between transmission and receipt of a signal using a polar satellite was frequently misinterpreted as meaning that the transmission would take a shorter time.

PHYSICS

Paper 9702/43
A2 Structured Questions

General comments

Well-prepared candidates were able to fully access the paper and achieve credit for this.

A significant number of candidates performed distinctly better in ***Section A*** than in ***Section B***. The performance of some candidates can be improved by emphasising the 'Applications of Physics' section of the syllabus.

Comments on Specific Questions

Section A

Question 1

(a)

(i) Many answers included statements such as 'angle swept out per unit time' or 'rate of change of angular displacement'. Comparatively few answers made it clear that it is the radius linking the Sun to the planet that creates this angle or angular displacement.

(ii) The correct expression was stated by the vast majority of the candidates.

(b) Most answers simply equated the centripetal force to the gravitational force. This gives the impression that there is an equilibrium situation. Candidates should make it clear that the centripetal force is provided by the gravitational force.

(c)

(i) There were many fully correct answers. The data for Venus needed to have the same units as the data for Neptune when used in the calculation.

(ii) This part of the question was generally well answered. The conversion of the period of Venus from units of years to seconds caused a problem for some candidates.

Question 2

(a) Very few answers stated four independent assumptions. Some candidates confused the bulk behaviour of the gas with the behaviour of individual atoms/molecules and stated that 'gases have random motion' or 'there are no forces between gases'.

(b) Good answers showed derivations that were methodically written out as a series of distinct steps. Candidates need to be advised that in questions such as this all the credit is awarded for the different stages of the derivation and not for the final answer that is already given in the question. Common errors included confusing the mass of a molecule with the mass of the gas and confusing the number of molecules with the number of moles of gas.

(c)

(i) Nuclear fusion was identified in most cases, although only a minority of candidates explained that this was because of the build up of a more massive nucleus from light nuclei.

(ii) Very few candidates realised that a deuterium nucleus can be assumed to have the same average kinetic energy as a proton i.e. 1.2×10^{-14} J.

(iii) The assumption is not valid because the proton and the deuterium nucleus are both positively charged so that they repel. Comments by candidates that related to the high value of calculated temperature for nuclear fusion were not relevant.

Question 3

(a)

(i) The majority of answers identified the correct distance, although an incorrect distance of 4.0 cm was sometimes stated.

(ii) Most candidates correctly calculated the number of oscillations per second, although a minority wrongly stated either 220 or the time for one oscillation.

(iii) With few exceptions, the correct position of the piston was shown.

(iv) This part of the question was generally well answered. A small minority of candidates used frequency instead of angular frequency in their calculation.

(b)

(i) Most candidates were able to identify the correct direction of movement of the piston, but were less successful in calculating its position.

(ii) As for **(b)(i)**, most candidates were able to identify the correct direction of movement of the piston, but did not understand how to calculate its position.

(iii) Only a minority of candidates were able to use the formula that is provided on the formula sheet to calculate the speed of the piston in cylinder Y. A few candidates managed to calculate the correct speed by differentiating the equation stated in **(a)**, although it should be noted that this alternative method of calculation is beyond the mathematical requirements of the syllabus.

Question 4

(a)

(i) Some answers missed out key words. It is the work done in bringing a unit positive charge from infinity to the point.

(ii) With few exceptions, a correct definition was given.

(b)

(i) The capacitance was usually calculated correctly. Some candidates made power-of-ten errors or thought that the capacitance was represented by the gradient of the graph.

(ii) The calculation presented very few problems.

(c) The energy lost was usually calculated correctly by subtracting the final electric potential energy from the initial electric potential energy of the sphere.

Question 5

(a) Apart from power-of-ten errors, the calculation caused few problems.

(b)

(i) The correct solution was to use the magnetic flux calculated in **(a)** in conjunction with Faraday's law of electromagnetic induction. A small minority of candidates wrongly calculated the e.m.f. in the wire as 8.4×10^{-3} V by performing a backwards calculation from the approximate current in the wire stated in **b(ii)** of the question.

(ii) This was a straightforward calculation for those candidates who had successfully completed **(b)(i)**.

(c) Most candidates commented that the force would be too small to be felt. However, very few responded to the instruction in the question to '*explain quantitatively*' by calculating the magnitude of this force.

Question 6

(a) Many answers were only partially correct. Power depends upon the square of the current, so it will be independent of current direction because the square is always positive.

(b) It was common to see the symbol for current used without any clear explanation as to whether it represented the root-mean-square current or the peak value of current. Good answers carefully explained all the terms that were used and methodically presented each of the distinct steps that lead up to the final answer.

Question 7

(a) Most derivations included a statement that the force due to the electric field is equal in magnitude to the force due to the magnetic field, but omitted the necessary condition that these two forces must also be opposite in direction.

(b) Key details were missing from most explanations. Although the particle entering the crossed fields now has a different charge and mass, these quantities are not involved in the expression $v = E/B$. The magnitudes of v, E and B have not changed and therefore there will be no deviation.

Question 8

(a) Some candidates stated that the threshold frequency is the minimum frequency for an electron to be emitted, without making it clear that it is the minimum frequency of electromagnetic radiation or light.

(b) Candidates chose a variety of ways to answer this part of the question. Some compared the wavelength of the second lamp with the threshold wavelength of the zinc plate. Others compared the frequency with the threshold frequency or compared the photon energy with the work function. A small minority of candidates added the energy of a photon from the first lamp to the energy of a photon from the second lamp and then incorrectly compared their total energy to the work function of the zinc plate.

Section B

Question 9

(a)

(i) It was generally understood that sharpness relates to the ease with which the edges of structures can be determined.

(ii) The most commonly identified factors were the area of the target anode and the size of the aperture through which the X-ray beam passes. Other factors, such as the amount of scattering of the X-ray photons, were less frequently described. Only a small minority of candidates wrongly mentioned factors that would affect contrast rather than sharpness.

(b) Candidates tended to write down what they knew about X-ray imaging and CT scanning without applying it to the question. An X-ray image only involves a single exposure. A CT scan, however, involves the exposure of a single slice from many different angles. This is then repeated for different slices. Therefore a CT scan involves a much greater exposure.

Question 10

(a) Most answers correctly recalled three properties of an ideal operational amplifier.

(b)

(i) The best answers clearly explained the polarity of the output for both the open and closed positions of the switch. However, there were many answers that only considered the output for one of the two possible switch positions. Weaker candidates had problems in understanding the operation of the potential dividers at the inputs of the operational amplifier.

(ii) In many cases the circuit symbol for a light-emitting diode (LED) was incorrect. It was often confused with the symbol for a diode. Candidates need to be able to recall and use the circuit symbols for all the components referred to in the syllabus. Those candidates that were able to draw the LEDs in the correct configuration were usually able to identify which was the green one.

Question 11

(a) The majority of candidates recalled the appropriate equation. Some calculations contained power-of-ten errors.

(b) A clear and precise explanation was needed in order to gain full credit. Many explanations correctly compared the attenuation of X-ray radiation in each type of substance. However, the differences in attenuation were rarely linked to the contrast.

Question 12

(a)

(i) It was generally understood that a digital signal consists of a series of high and low voltages. Comparatively fewer candidates understood that an analogue signal is an information signal that has the same variation as the information itself. Some candidates wrongly thought that an analogue signal was any signal with a sinusoidal shape.

(ii) Well-prepared candidates were able to recall two advantages of transmitting data in digital form. Firstly, extra bits of data can be added to a digital signal to enable the checking and correcting of errors when the signal arrives at the receiving system. Secondly, regenerator amplifiers enable noise to be eliminated when a digital signal is amplified so that the signal is regenerated back to its original shape. Some answers were too incomplete to be awarded any credit, such as 'extra data can be added to the signal' or 'the signal has no noise'.

(b)

(i) An analogue-to-digital converter samples the analogue signal at regular time intervals and then converts each sample into a binary number. There were many vague answers such as 'it converts an analogue signal to a digital signal'.

(ii) Very few candidates realised that one channel is allocated for each bit of the binary number.

PHYSICS

Paper 9702/51
Planning, Analysis and Evaluation

General comments

Question 2 was generally answered better than **Question 1** and a large number of candidates scored very highly. It was evident that Centres had spent time on the analysis section enabling their candidates to achieve full credit. In **Question 1**, many candidates did not realise that an alternating current was required in coil X; candidates should also include greater detail in their answers. In **Question 2**, careless mistakes were often made in the plotting of points on the graph and there were some power of ten errors. **Question 1** had a number of boxes at the end of the question that are for the Examiner's use; they do also give a useful hint to candidates about the criteria used for awarding credit.

As has been mentioned before, this paper is designed to test candidates' practical experience; this is best achieved through the teaching of a practical course where the skills required for this paper are developed and practised over a period of time with a 'hands-on' approach. To assist Centres, CIE have produced two booklets – Teaching AS Physics Practical Skills and Teaching A2 Physics Practical Skills that are available from the Teacher Support Website.

Comments on Specific Questions

Question 1

Candidates were required to design a laboratory experiment to investigate how the emf *V* in a coil Y depends on the frequency of the current in coil X.

Credit was awarded for correctly identifying the independent and dependent variables; some candidates were not awarded credit because they referred to the independent variable as 'current in coil X' as opposed to 'frequency of current in coil X'. When defining the problem, candidates should then consider the variables that will need to be kept constant. In this question credit was awarded for stating explicitly that the current in coil X would be kept constant and for either keeping the number of turns on coil Y or the area of coil Y constant. As indicated in previous reports the word 'controlled' is not acceptable.

Further credit was available for the methods of data collection. Candidates are expected to draw a labelled diagram of equipment suitable for the experiment. Credit was awarded for clearly indicating two independent coils which were labelled X and Y; it is important that candidates take care over their diagrams and in this case ensure that it was clear that the coils were independent and not joined together. Coil X needed to be connected to an alternating supply – many candidates just connected coil X to a cell or battery. Again clear labelling was needed to indicate the alternating supply. Some candidates were not awarded credit because they had connected a cathode ray oscilloscope (CRO) in series with the alternating power supply. Good candidates clearly indicated the use of a signal generator. Most candidates were awarded credit for connecting coil Y to a voltmeter or CRO. Candidates should ensure that their circuit diagrams are complete and should use the accepted symbols. Some candidates incorrectly suggested that the frequency of the current could be changed by changing the resistance of the rheostat.

Further credit was available for the method of keeping the current in coil X constant, e.g. by using a rheostat, and for the method of determining the frequency of the current in coil X. Both these points enabled additional detail credit to be awarded. An explanation of how to use an ammeter or CRO to measure the current and detail on measuring the frequency using the timebase of the CRO with a sketch diagram would have also gained additional detail credit. Explicit statements are required.

Further credit was available for the analysis of the data. It is expected that candidates would state the quantities that should be plotted on each axis of a graph; many candidates suggested plotting a graph of *V* against *f*. Other logically valid graphs were credited. Credit was also awarded for explaining that the relationship is valid if the graph is a straight line passing through the origin. Candidates who plotted log *V* against log *f* and then stated that the graph should be a straight line with a gradient equal to one scored full credit.

Credit was available for describing an appropriate safety precaution. Candidates should be encouraged to ensure that the safety precaution(s) is (are) relevant to the experiment and clearly reasoned; vague answers did not gain credit. Creditworthy responses included precautions linked to the hot coils, e.g. switch off when not in use etc. Credit was not awarded for references to heating of wires since this was considered too vague.

Further credit was available for additional detail. Candidates should be encouraged to write their plans including appropriate detail; too often candidates' answers lacked sufficient practical detail. Vague responses did not score. In addition to the points already mentioned above, credit was also given for:

- methods to increase the induced emf, e.g. using a large current in coil X or a large number of turns on coil Y or the use of an iron core,
- detail of measuring the induced emf using a CRO, e.g. height of trace × *y*-gain of a calibrated CRO,
- avoiding alternating magnetic fields,
- using insulated wire for the coils,
- keeping the relative positions of the coil X and coil Y the same.

Usually, good candidates who have followed a 'hands on' practical course during their studies are awarded credit for additional detail. It is essential that candidates' answers give detail relevant to the experiment in the question rather than general "text book" rules for working in a laboratory.

Question 2

In this data analysis question candidates were given data for an experiment where a student investigates how the period *T* of a simple pendulum depends on its length *l*.

(a) This part asked candidates to express the gradient and *y*-intercept of a graph of lg *T* against lg *l* in terms of *a* and *b*. This was generally well answered although a few candidates incorrectly used 'ln'.

(b) Most candidates correctly completed the table of results, finding values for lg *l* and lg *T* and the absolute uncertainty in lg *T*. Candidates who did not gain credit either did not record their values to an appropriate number of significant figures or made rounding errors. In logarithmic quantities the number of significant figures is determined by the number of decimal places, thus the number of decimal places in a logarithmic quantity should be the same or one more than the number of significant figures in the raw data. The absolute uncertainties in lg *T* were usually calculated correctly although there were a small number of 'power of ten' errors; the Examiners allow different methods for finding uncertainties and do not penalise significant figures at this stage. Sometimes the maximum difference was calculated without dividing by two.

(c)

(i) The graph plotting was generally good. Common mistakes included not plotting the points correctly - candidates should check suspect plots. On this particular question a number of candidates plotted the error bars in reverse.

(ii) Most candidates attempted to draw the line of best fit. The worst acceptable straight line should either be the steepest possible line or the shallowest possible line that passes through the error bars of all the data points used for the line of best fit. The majority of the candidates labelled clearly the lines on their graph; lines not indicated may be penalised.

(iii) This was generally answered well, although candidates could often make their working clearer. Some candidates did not use a sensibly sized triangle for their gradient calculation. To determine the absolute error in the gradient, candidates were expected to find the difference between the gradient of the line of best fit and the gradient of the worst acceptable line. A large number of good candidates clearly indicated the points that they used from the line of best fit.

(iv) Candidates should have determined the *y*-intercept by substituting a point on the line of best fit into $y = mx + c$ and have obtained a negative value; some candidates incorrectly read the *y*-intercept directly from the *y*-axis. Many candidates clearly used a point from the gradient calculation of their line of best fit. To determine the uncertainty in the *y*-intercept, it was expected that candidates would substitute a point on the worst acceptable line into $y = mx + c$ using the gradient of the worst acceptable line and then find the difference. A number of candidates were not awarded credit owing to either using the wrong gradient and/or substituting in the wrong points.

(d) To determine *a* candidates often correctly equated *a* to $10^{y\text{-intercept}}$; a significant number of candidates incorrectly equated *a* to $e^{y\text{-intercept}}$. Candidates who determined the *y*-intercept incorrectly in **(c)(iv)** were not penalised in this part. The value of *b* needed to be the same as the candidate's gradient value and had to be given to two or three significant figures. Credit is often available for the quality of the results which was awarded at this point for the accuracy of *b*. Further credit was for correctly determining the uncertainty in the values of *a* and *b*. The latter value corresponded to the uncertainty in the gradient while to determine the uncertainty in *a* required the worst value to be calculated and the difference found. Some candidates found the difference between the maximum and minimum values but did not divide by two. Credit could only be awarded here if the method was clear; too often values were written by candidates without demonstrating that they understood the underlying Physics.

PHYSICS

Paper 9702/52

Planning, Analysis and Evaluation

General comments

Question 2 was generally answered better than **Question 1** and a large number of candidates scored very highly. It was evident that Centres had spent time on the analysis section enabling their candidates to achieve full credit. In **Question 1**, many candidates did not realise that an alternating current was required in coil X; candidates should also include greater detail in their answers. In **Question 2**, careless mistakes were often made in the plotting of points on the graph and there were some power of ten errors. **Question 1** had a number of boxes at the end of the question that are for the Examiner's use; they do also give a useful hint to candidates about the criteria used for awarding credit.

As has been mentioned before, this paper is designed to test candidates' practical experience; this is best achieved through the teaching of a practical course where the skills required for this paper are developed and practised over a period of time with a 'hands-on' approach. To assist Centres, CIE have produced two booklets – Teaching AS Physics Practical Skills and Teaching A2 Physics Practical Skills that are available from the Teacher Support Website.

Comments on Specific Questions

Question 1

Candidates were required to design a laboratory experiment to investigate how the emf V in a coil Y depends on the frequency of the current in coil X.

Credit was awarded for correctly identifying the independent and dependent variables; some candidates were not awarded credit because they referred to the independent variable as 'current in coil X' as opposed to 'frequency of current in coil X'. When defining the problem, candidates should then consider the variables that will need to be kept constant. In this question credit was awarded for stating explicitly that the current in coil X would be kept constant and for either keeping the number of turns on coil Y or the area of coil Y constant. As indicated in previous reports the word 'controlled' is not acceptable.

Further credit was available for the methods of data collection. Candidates are expected to draw a <u>labelled</u> diagram of equipment suitable for the experiment. Credit was awarded for clearly indicating two independent coils which were labelled X and Y; it is important that candidates take care over their diagrams and in this case ensure that it was clear that the coils were independent and not joined together. Coil X needed to be connected to an alternating supply – many candidates just connected coil X to a cell or battery. Again clear labelling was needed to indicate the alternating supply. Some candidates were not awarded credit because they had connected a cathode ray oscilloscope (CRO) in series with the alternating power supply. Good candidates clearly indicated the use of a signal generator. Most candidates were awarded credit for connecting coil Y to a voltmeter or CRO. Candidates should ensure that their circuit diagrams are complete and should use the accepted symbols. Some candidates incorrectly suggested that the frequency of the current could be changed by changing the resistance of the rheostat.

Further credit was available for the method of keeping the current in coil X constant, e.g. by using a rheostat, and for the method of determining the frequency of the current in coil X. Both these points enabled additional detail credit to be awarded. An explanation of how to use an ammeter or CRO to measure the current and detail on measuring the frequency using the timebase of the CRO with a sketch diagram would have also gained additional detail credit. Explicit statements are required.

Further credit was available for the analysis of the data. It is expected that candidates would state the quantities that should be plotted on each axis of a graph; many candidates suggested plotting a graph of V against f. Other logically valid graphs were credited. Credit was also awarded for explaining that the relationship is valid if the graph is a straight line passing through the origin. Candidates who plotted log *V* against log *f* and then stated that the graph should be a straight line with a gradient equal to one scored full credit.

Credit was available for describing an appropriate safety precaution. Candidates should be encouraged to ensure that the safety precaution(s) is (are) relevant to the experiment and clearly reasoned; vague answers did not gain credit. Creditworthy responses included precautions linked to the hot coils, e.g. switch off when not in use etc. Credit was not awarded for references to heating of wires since this was considered too vague.

Further credit was available for additional detail. Candidates should be encouraged to write their plans including appropriate detail; too often candidates' answers lacked sufficient practical detail. Vague responses did not score. In addition to the points already mentioned above, credit was also given for:

- methods to increase the induced emf, e.g. using a large current in coil X or a large number of turns on coil Y or the use of an iron core,
- detail of measuring the induced emf using a CRO, e.g. height of trace × *y*-gain of a calibrated CRO,
- avoiding alternating magnetic fields,
- using insulated wire for the coils,
- keeping the relative positions of the coil X and coil Y the same.

Usually, good candidates who have followed a 'hands on' practical course during their studies are awarded credit for additional detail. It is essential that candidates' answers give detail relevant to the experiment in the question rather than general "text book" rules for working in a laboratory.

Question 2

In this data analysis question candidates were given data for an experiment where a student investigates how the period *T* of a simple pendulum depends on its length *l*.

(a) This part asked candidates to express the gradient and *y*-intercept of a graph of lg *T* against lg *l* in terms of *a* and *b*. This was generally well answered although a few candidates incorrectly used 'ln'.

(b) Most candidates correctly completed the table of results, finding values for lg *l* and lg *T* and the absolute uncertainty in lg *T*. Candidates who did not gain credit either did not record their values to an appropriate number of significant figures or made rounding errors. In logarithmic quantities the number of significant figures is determined by the number of decimal places, thus the number of decimal places in a logarithmic quantity should be the same or one more than the number of significant figures in the raw data. The absolute uncertainties in lg *T* were usually calculated correctly although there were a small number of 'power of ten' errors; the Examiners allow different methods for finding uncertainties and do not penalise significant figures at this stage. Sometimes the maximum difference was calculated without dividing by two.

(c)

(i) The graph plotting was generally good. Common mistakes included not plotting the points correctly - candidates should check suspect plots. On this particular question a number of candidates plotted the error bars in reverse.

(ii) Most candidates attempted to draw the line of best fit. The worst acceptable straight line should either be the steepest possible line or the shallowest possible line that passes through the error bars of all the data points used for the line of best fit. The majority of the candidates labelled clearly the lines on their graph; lines not indicated may be penalised.

(iii) This was generally answered well, although candidates could often make their working clearer. Some candidates did not use a sensibly sized triangle for their gradient calculation. To determine the absolute error in the gradient, candidates were expected to find the difference between the gradient of the line of best fit and the gradient of the worst acceptable line. A large number of good candidates clearly indicated the points that they used from the line of best fit.

(iv) Candidates should have determined the *y*-intercept by substituting a point on the line of best fit into $y = mx + c$ and have obtained a negative value; some candidates incorrectly read the *y*-intercept directly from the *y*-axis. Many candidates clearly used a point from the gradient calculation of their line of best fit. To determine the uncertainty in the *y*-intercept, it was expected that candidates would substitute a point on the worst acceptable line into $y = mx + c$ using the gradient of the worst acceptable line and then find the difference. A number of candidates were not awarded credit owing to either using the wrong gradient and/or substituting in the wrong points.

(d) To determine *a* candidates often correctly equated *a* to $10^{y\text{-intercept}}$; a significant number of candidates incorrectly equated *a* to $e^{y\text{-intercept}}$. Candidates who determined the *y*-intercept incorrectly in **(c)(iv)** were not penalised in this part. The value of *b* needed to be the same as the candidate's gradient value and had to be given to two or three significant figures. Credit is often available for the quality of the results which was awarded at this point for the accuracy of *b*. Further credit was for correctly determining the uncertainty in the values of *a* and *b*. The latter value corresponded to the uncertainty in the gradient while to determine the uncertainty in *a* required the worst value to be calculated and the difference found. Some candidates found the difference between the maximum and minimum values but did not divide by two. Credit could only be awarded here if the method was clear; too often values were written by candidates without demonstrating that they understood the underlying Physics.

PHYSICS

Paper 9702/53

Planning, Analysis and Evaluation

General comments

Question 2 was generally answered better than **Question 1** and a large number of candidates scored very highly. It was evident that Centres had spent time on the analysis section enabling their candidates to achieve full credit. For **Question 1** candidates should include greater detail in their answers, while for **Question 2** careless mistakes were often made in the plotting of points on the graph and there were some power of ten errors. **Question 1** had a number of boxes at the end of the question that are for the Examiner's use; they do also give a useful hint to candidates about the criteria used for awarding credit.

As has been mentioned before, this paper is designed to test candidates' practical experience; this is best achieved through the teaching of a practical course where the skills required for this paper are developed and practised over a period of time with a 'hands-on' approach. To assist Centres, CIE have produced two booklets – Teaching AS Physics Practical Skills and Teaching A2 Physics Practical Skills that are available from the Teacher Support Website.

Comments on Specific Questions

Question 1

Candidates were required to design a laboratory experiment to determine the resistivity of aluminium in the form of a strip with approximate given dimensions.

Credit was available for correctly identifying the independent and dependent variables, which was often not answered well owing to the orientation of the strip chosen by candidates. The data given in the question is designed to help the candidates; using the data, the greatest resistance would be obtained with a long length and small cross-sectional area and this is approximately 0.001 Ω. Candidates should also use the labelling on the diagram (Fig. 1.1) to explain their answers. Further credit was then available for stating which other quantities should be kept constant; this depended on the orientation chosen, but if *c* is varied then *d* or *A* should be constant. Secondly, the temperature of the strip should be constant. Candidates choosing a different orientation were expected to state which other dimension would need to be constant logically. As indicated in previous reports the word 'controlled' is not acceptable.

Credit was available for the methods of data collection. Candidates are expected to draw a diagram of equipment suitable to measure resistance; circuit diagrams should use appropriate symbols. Most candidates had drawn circuits containing ammeters and voltmeter. Other candidates used an ohmmeter. Incorrect circuit diagrams often contained voltmeters connected in series with ammeters or ohmmeters with power supplies. Credit was also available for showing how the aluminium strip was connected to a circuit using suitable electrodes. Weaker candidates often used crocodile clips for this. Good candidates suggested large electrodes to cover the whole area of the end of the aluminium strip or conducting putty.

Further credit was available for suitable methods to accurately measure one millimetre (*t*) and up to one metre (*c*) e.g. a micrometer screw gauge and a metre rule. Vernier callipers were not considered appropriate to measure *c*. The final mark in this section was for stating how a value for resistance was obtained from the apparatus shown in the diagram – candidates usually clearly indicating that the resistance was equal to the voltmeter reading divided by the ammeter reading or that they would record the ohmmeter reading.

Credit was available for the analysis of the data. It is expected that candidates would state the quantities that should be plotted on each axis of a graph; many candidates suggested plotting a graph of *R* against *c*. Other logically valid graphs were credited. Again, using the symbols used in Fig. 1.1 helped greatly. Credit was awarded for explaining how the resistivity could be found from the graph. Many weak candidates began this question by incorrectly stating that resistivity is the dependent variable and claimed that a graph of resistivity against length would be a straight line though the origin. In their answers candidates should indicate an appropriate graph to plot; no credit was awarded for calculating the resistivity several times and then determining the average.

Credit was available for describing an appropriate safety precaution. Candidates should be encouraged to ensure that the safety precaution(s) is (are) relevant to the experiment and clearly reasoned; vague answers did not gain credit. Creditworthy responses included precautions linked to sharp edges of cut aluminium or the process of cutting metals. Credit was not awarded for references to heating the aluminium since the temperature should be constant.

Further credit was available for additional detail. Candidates should be encouraged to write their plans including appropriate detail; too often candidates' answers lacked sufficient practical detail. Vague responses did not score. In addition to the points already mentioned above, credit was also given for:

- the method of holding or insulating the aluminium strip,
- taking many readings of the thickness of the strip along its length and then obtaining an average value,
- an estimate of the typical resistance of the given strip (in the order of 10^{-3} ohm), hence the need for a protective resistor, together with appropriate ranges for ammeter, voltmeter or ohmmeter. Some candidates suggested that an EHT power supply would be needed to give sufficient current through the aluminium.

Usually, good candidates who have followed a 'hands on' practical course during their studies are awarded credit for additional detail. It is essential that candidates' answers give detail relevant to the experiment in the question rather than general "text book" rules for working in a laboratory.

Question 2

In this data analysis question candidates were given data concerning the discharge of a capacitor through different values of a resistor.

(a) Candidates were asked to express the gradient of a graph of ln *V* against 1/*R* in terms of *C*. This was generally well answered although weaker candidates did not always include the negative sign.

(b) Most candidates correctly completed the table of results, finding values for *1/R* and ln *V* and its uncertainty. Many candidates either did not record their values to an appropriate number of significant figures or made rounding errors. It is expected that the number of significant figures in calculated quantities should be the same or one more that the number of significant figures in the raw data. In logarithmic quantities the number of significant figures is determined by the number of decimal places; thus the number of decimal places in a logarithmic quantity should be the same or one more than the number of significant figures in the raw data The absolute uncertainties in ln *V* were usually calculated correctly although there were a small number of 'power of ten' errors. The Examiners allow different methods for finding uncertainties and do not penalise significant figures at this stage. Sometimes the maximum difference was calculated without dividing by two.

(c)

(i) Graph plotting was generally good. Common mistakes included not plotting the points correctly - candidates should check suspect plots particularly when the scales in this case were more difficult to interpret. On this particular question a number of candidates plotted the error bars in reverse.

(ii) It was pleasing to see that most candidates attempted to draw the line of best fit. The worst acceptable straight line should be either the steepest possible line or the shallowest possible line that passes through the error bars of all the data points used for the line of best fit. Some candidates wrongly used the centroid of the best fit line to draw the worst acceptable line resulting in a line that was not the steepest possible (or shallowest possible). The majority of the candidates labelled clearly the lines on their graph; in future lines not indicated will be penalised.

(iii) This was generally answered well, although candidates could often make their working clearer. Some candidates did not use a sensibly sized triangle for their gradient calculation. To determine the absolute error in the gradient, candidates were expected to find the difference between the gradient of the line of best fit and the gradient of the worst acceptable line. A large number of good candidates clearly indicated the points that they had used from the line of best fit.

(d)

(i) Most candidates were awarded partial credit for correctly substituting into their expression from **(a)**. Further credit proved to be quite difficult to achieve for all but the best candidates since it required a correct unit and the value of *C*, given to two or three significant figures, to be within the permitted range. Substitution methods did not score.

(ii) The percentage uncertainty in *C* could be obtained either from *C* and its uncertainty or from the percentage uncertainty in the gradient. Many candidates did this correctly.

(e) Candidates needed to find a value for *R* that will cause the capacitor to discharge to 10% of the original potential difference in 15.0 s and to include the absolute uncertainty. Weaker candidates attempted to use the intercept from the graph to find the original potential difference, forgetting the false origin on the *x*-axis. Others used 0.9 instead of 0.1 for the ratio of the potential differences. However, many candidates gained credit here.

Candidates were able to use any appropriate method to determine the absolute uncertainty in *R*. Good candidates used the percentage uncertainty in their value for *C*, the percentage uncertainty in their gradient value or the difference in *R* derived from their best and worst value of *C*.