PHYSICS

Paper 9702/11
Multiple Choice

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

General Comments

The test showed a wide variation in the standard of the candidates. Questions **1**, **18** and **40** were found to be particularly easy, while **8**, **12**, **36** and **37** were found to be difficult.

It is challenging for candidates to manage their time when completing multiple choice papers. Not all the questions take the same time to analyse, so candidates should use time gained on the simpler questions to give further thought to more complex questions. Candidates should be advised never to take a disproportionate length of time over one question, but if a question is omitted at any stage it is crucial that a corresponding space is left on the answer sheet.

Comments on Specific Questions

Question 5

Many candidates thought that the problem was just one of radius and diameter, but that is missing the point. If there is a 0.2 % uncertainty in the diameter, then there will be a 0.6 % uncertainty in the volume.

Question 8

A large number of candidates gave answer **D**, but averages are not that simple unless the two times are the same and not the two distances. Careful analysis is needed to find the average speed here as 480 km h^{-1}. One method would be to work out the time to travel distance *d* on each half of the journey, then use average speed = total distance / total time.

Question 10

Gravitational force does not alter when the spacecraft is launched, so the answer here is **B**.

Question 12

When a body is moving through air to the left, there will be a drag force acting on it to the right, as well as its weight. The answer here is **D**, but both **A** and **C** were more popular responses.

Question 14

Many candidates forgot (or did not read carefully) that there are two strings, and then gave **B** rather than the correct answer **D**.

Question 23

Modelling clay cannot possibly be elastic or brittle, so **D** is the correct answer.

Question 28

It would help candidates if they would write on the question paper when answering a multiple choice paper. If, in answering this question, they drew a line bisecting angle α they could obtain $\frac{1}{2}\alpha = \sin^{-1}(\lambda/d)$ and hence obtain **D** as the correct answer.

Question 34

D is an obvious reaction, but when the current is worked out for the two lamps it is found to be the same for both, so the correct answer is **B**.

Question 36

Candidates found this question difficult. The voltmeter has a very high resistance, so there will be no current through it for any position of the slider. Therefore there will be no p.d. across P, and the voltmeter will always record just the p.d. across Q, and this will be 4.0 V.

Question 37

Many candidates answered this well, but some needed to realise that the potential starts high (at X) and ends low (at Y) so the answer is **D** and not **A**.

PHYSICS

Paper 9702/12
Multiple Choice

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

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PHYSICS

Paper 9702/13
Multiple Choice

Question Number	*Key*	*Question Number*	*Key*
1	**D**	21	**C**
2	**B**	22	**C**
3	**D**	23	**D**
4	**A**	24	**C**
5	**D**	25	**A**
6	**D**	26	**A**
7	**B**	27	**D**
8	**B**	28	**B**
9	**D**	29	**A**
10	**C**	30	**C**
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16	**A**	36	**D**
17	**D**	37	**C**
18	**D**	38	**C**
19	**C**	39	**D**
20	**B**	40	**A**

General Comments

The test showed a wide variation in the standard of the candidates. **Questions 8**, **10**, **18**, **20**, **21**, **23** and **39** were found to be easy. At the other end of the scale, **Questions 1** and **36** were particularly difficult.

It is challenging for candidates to manage their time when completing multiple choice papers. Not all the questions take the same time to analyse, so candidates should use time gained on the simpler questions to give further thought to more complex questions. Candidates should be advised never to take a disproportionate length of time over one question, but if a question is omitted at any stage it is crucial that a corresponding space is left on the answer sheet.

Comments on Specific Questions

Question 1

The estimate required in the first question caused many problems. The kinetic energy of the bus might well be 10^6 J. Domestic lights are usually around 60 W (often less) and an oven at 300 K is not hot. The correct

answer, **D**, indicates just how large a cubic metre is. Candidates could have obtained this answer by making a rough estimate of the size of a tyre and determining the volume from this.

Question 2

Many candidates did not distinguish between an ampere second and an ampere per second and therefore gave **A** as the answer instead of **B**.

Question 3

This question illustrated the need for candidates to write on the question paper. A vector diagram here would show how a balancing force must be pointing south-west.

Question 6

Uncertainties caused problems here. The mass has an uncertainty of 1 % and the diameter has an uncertainty of 0.9 %. Density, therefore, has an uncertainty of (1 + 3 × 0.9) % = 3.7 %. Both **A** and **C** were popular incorrect answers.

Question 14

A and **B** were both popular responses. The correct answer is **B**. For zero torque the line of action of all three forces must go through a single point.

Question 31

A and **B** were popular answers, but electric field is always force per unit charge so the answer is F/q, i.e. **D**. The charge in the expression is that on which the force acts (not the charge creating the field), so q is involved rather than Q.

Question 32

A quick sketch graph would have prevented many mistakes in answering this question. The average current is 60 mA and not 80 mA, so 60 mA × 8 s = 480 mC.

Question 33

Many learners of physics think that electrons slow down in a resistor. They do not. They speed up to release energy. (A similar situation is that water speeds up when it moves from a river to a waterfall.) The current is the same in each of the wires as they are in series.

Question 34

Candidates found this question difficult. A spurious ratio method can be used to get the value 44 W. One correct method would be to use $P = I^2R$ to obtain the current in the device (0.45 A), and then use Kirchhoff's second law in the form $E = \Sigma IR$ to determine the resistance of the variable resistor.

Question 36

This was one of the most difficult questions on the paper, and each of the answers was chosen by many candidates. There is no break in the positive wire if the potential at X is 24 V. A break in the connection within the motor would give 24 V at X and 0 at Y. A break in the negative wire would give 24 V at Y. **D** is correct because there is no current passing and so no drop in potential across the motor.

Question 37

C and **D** were both popular. **C** is correct because the resistance of a thermistor does not vary linearly with temperature.

Question 38

Analysis of the circuit shows that a 7 V drop across L must mean a 13 V drop across M (to obtain a total 20 V across L and M). A drop of 7 V across L plus a 4 V drop across N must mean an 11 V drop across P. With 11 V across P there must be 9 V across Q, so the answer is **C**.

PHYSICS

Paper 9702/21
AS Structured Questions

Key Messages

- There are many situations where candidates lose credit because they do not explain their work. This is especially true where the correct answer has not been determined. In these circumstances, credit for correct working or procedures cannot be awarded. Candidates should be encouraged always to explain their work, including initial statements and the quoting of relevant formulae.

- Candidates should be encouraged to read the command words used in each question carefully. "State and explain" indicates that an explanation is a required part of the answer. Candidates often lose credit for this type of question when they provide only a statement without an explanation.

- Questions that ask for a specific reference to details given on graphs or diagrams should be answered with specific reference to these details, and should not be answered merely in general terms.

- Physics is a precise science. Candidates at this level should choose key words with care when writing any explanation. The distinction between terms such as mass and weight, stress, strain and force, and size and shape should be appreciated. Definitions and principles should be learnt in the detail stated in the learning outcomes in the syllabus.

General Comments

There appeared to be little difficulty for most candidates to complete their answers in the allotted time. In general, candidates who did not complete the last question had also left earlier parts of questions unanswered.

The marks scored by candidates had a very wide range. There were some parts of questions that demanded little more than straightforward knowledge. Conversely, some sections were demanding. These required an ability to apply knowledge to different situations.

Candidates do need to realise that knowledge of the syllabus content is insufficient to score highly. They need to have an understanding of what they have learned and should be able to apply this knowledge to new situations.

Comments on Specific Questions

Question 1

This question was answered well by nearly all well prepared candidates.

(a) This was a straightforward introductory question to help the candidates settle into the examination and which caused little difficulty for the average candidate. Kelvin and ampere were the most common answers, although candela and mole were also stated by some candidates.

(b) (i) This was generally answered correctly. A variety of correct energy equations were used by the candidates. A very small minority thought that work done was equal to force/weight multiplied by length.

(ii) This question differentiated the candidates. A good starting point was to list the base units for each of the terms involved in the given equation. A number of candidates did not include the powers for some of the terms in the equation. The processing of the indices proved difficult for some

candidates. Occasionally, the cancelling of units was poorly presented, making it difficult for the candidates to keep track of what base units had been cancelled. The division of units with negative indices also caused some difficulty. For example s^{-2}/s^{-4} was often stated as s^{-2} instead of s^2.

Question 2

This proved to be the most difficult question on the paper for many candidates. The majority of the candidates appear to be familiar with using an oscilloscope for taking measurements related to waves, but found the context of this question difficult.

(a) There were many attempts at using $v = f\lambda$ to solve the problem. It would appear that candidates had only used the cathode-ray oscilloscope to study wave patterns and had not used it for basic timing between emitted and reflected pulses. A significant number of candidates were unable to determine the correct number of centimetres between the emitted and reflected pulses. Many also did not appreciate that a radio wave pulse would travel at a speed of $3 \times 10^8\,\text{m}\,\text{s}^{-1}$ and tried many different ways to calculate a velocity for the pulse.

(b) Very few candidates determined the time-base setting using the ratio of the speeds. The majority of candidates that tried to determine the time-base setting used the inappropriate wave equation again in this part. A few candidates were able to gain marks completing an error carried forward calculation from an incorrect distance in part **(a)**. A significant number of candidates made no attempt at this part.

Question 3

The majority of candidates gained marks in **(a)** and **(b)**. Candidates of high ability gave correct answers in **(c)**. Many candidates did not appear to have read this part of the question carefully enough to link the information given with the questions asked.

(a) What is meant by *work done* was often stated with insufficient precision. Almost all answers vaguely referred to "force multiplied by distance", but were usually incomplete in the sense that they did not mention 'moved' or 'in the direction of the force'. A significant number of candidates included the 'perpendicular' distance in their definition.

(b) This was generally well answered.

(c) (i) Candidates do not seem to be familiar with dynamics questions in which the force or acceleration is not constant. A common error made here was to assume that the force and therefore the acceleration were constant, leading to a calculation based on an inappropriate equation of uniformly accelerated motion. Very few candidates realised that the work done bringing the trolley to rest could be determined from the area under the line on the force-displacement graph.

(ii) The majority of candidates who attempted this part usually drew an incorrect straight line. There was no connection made between the increase in the opposing force with distance and the increase in deceleration with distance. Hence the variation of the velocity with distance did not show the required increase in gradient.

Question 4

This question produced a wide variety of solutions. Candidates would benefit from further study of the concept of torque.

(a) The definition caused few problems for well-prepared candidates. Weaker candidates lacked precision and failed to refer to '<u>one</u> of the forces' or the <u>perpendicular</u> distance between them. Many candidates gave a general description of a moment of a force or simply described a couple.

(b) (i) Candidates should read the question carefully. Many stated the name and direction of the forces, but did not say where they act. Incorrect forces included 'air resistance', 'friction', 'centripetal force', 'resultant force' and 'normal force'. Many candidates lost credit because they did not answer the question fully.

(ii) There were many answers that were either incorrect by a factor of 2 or else contained a power-of-ten error.

(iii) Again, candidates should read the question carefully. Many answers did not refer to the four forces acting on the wheel. Unfortunately, many of the answers that did refer to the four forces also used terms such as 'balance' and 'cancel' instead of 'equal and opposite'.

(iv) A minority of candidates explained that the wheel was not in equilibrium because although the resultant force was zero there was a resultant torque. There were many candidates who thought the wheel was in equilibrium because the resultant force was zero, even though the torque on the wheel had been calculated in **(b)(ii)**.

Question 5

This question revealed some gaps in the knowledge and understanding of many candidates on this topic.

(a) (i) Only a small number of answers had the required level of precision to be awarded credit. Many answers referred to either the 'distance moved' by the particles from the equilibrium position or else described the distance of 'the wave' from the equilibrium position. Many of those who did write distance from the equilibrium position did not mention the particles or the rope.

(ii) **1.** A very small number of candidates gave the correct answer of 20 mm. Usually, 40 mm or 80 mm were seen, indicating that candidates did not understand the meaning of 'amplitude' or did not read the question carefully.

2. This was generally answered well.

(b) Fully correct answers were rare. Many candidates were unable to visualise the new position of the rope after a further 0.050s. A few thought that it was a stationary wave and so drew a horizontal line along the equilibrium position. Unfortunately, some of the candidates that did understand the situation went on to give sketches that were not sufficiently clear. A significant number made no attempt at this part.

(c) (i) This part of the question caused few problems for well-prepared candidates. A significant number suggested that the wave was stationary even though the wave had not reached the end point B. Many gave a one word answer with no explanation. These candidates should be encouraged to read the question carefully and to pay attention to the command words.

(ii) Many answers were either incomplete or lacked the required level of precision at this level.

Question 6

There were some good answers to this question. Weaker candidates found the calculations difficult.

(a) This definition was poorly answered. Many candidates gave a statement for potential difference that was a description but not a definition. For example "the work done (or energy transferred) when unit charge is moved between two points". The idea of a ratio was missing. A number of candidates also referred to '1 coulomb' rather than 'unit charge'. There seemed to be a lack of understanding of the precise wording required for a correct definition as opposed to an explanation of a quantity.

(b) (i) This part was generally well answered by the majority of candidates. There were some power-of-ten errors in the resistivity and cross-sectional area.

(ii) The correct equation was usually given. However, when calculating the total resistance of the circuit, candidates were often unable to visualise the two wires as being two resistors in series with the heater resistance. The resistance of one or both wires was omitted. In some cases the resistance of the heater was omitted.

(iii) Many candidates attempted to use either $P = \mathcal{I}V$ or $P = V^2/R$, with 240 V substituted for potential difference across each wire. A significant number of those who did use $P = \mathcal{I}^2R$ only calculated the power loss in *one* wire.

(c) A significant number of candidates were able to score the first mark, but only a tiny minority were then able to explain why this leads to an increase in power loss in the cable. Explanations were given in terms of reduced current or constant current or constant potential difference. In this section many candidates stated that the cross-sectional area increased or doubled. The given areas were misread or not read carefully.

Question 7

This question was generally well answered by many candidates.

(a) (i) The majority of candidates gave acceptable answers. A common error was to give a statement that referred to the field lines rather than to give a similarity of the electric fields. There was also reference to the charge on the plates or that both fields/field lines go/travel from positive to negative.

(ii) This part was generally well answered with full credit awarded to many candidates. A significant number of candidates were imprecise and indicated a decreased voltage or potential difference without indicating that this is between the plates.

(iii) This part of the question was effective at differentiating the candidates. The most common correct answer was that the α-particles and β-particles have opposite charge. Many answers referred to α-particles being 'heavier', rather than more massive, than β-particles. The least understood reason was that β-particles have a range of energies while α-particles have the same energy. There were a significant number of incomplete answers, such as those describing a property of the α-particle but not comparing it with the same property of the β-particle.

(b) This was generally well answered.

(c) This was generally well answered.

PHYSICS

Paper 9702/22
AS Structured Questions

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PHYSICS

Paper 9702/23
AS Structured Questions

Key Messages

- There are many situations where candidates lose credit because they do not explain their work. This is especially true where the correct answer has not been determined. In these circumstances, credit for correct working or procedures cannot be awarded. Candidates should be encouraged always to explain their work, including initial statements and the quoting of relevant formulae.

- Candidates should be encouraged to read the command words used in each question carefully. "State and explain" indicates that an explanation is a required part of the answer. Candidates often lose credit for this type of question when they provide only a statement without an explanation.

- Questions that ask for a specific reference to details given on graphs or diagrams should be answered with specific reference to these details, and should not be answered merely in general terms.

- Physics is a precise science. Candidates at this level should choose key words with care when writing any explanation. The distinction between terms such as mass and weight, stress, strain and force, and size and shape should be appreciated. Definitions and principles should be learnt in the detail stated in the learning outcomes in the syllabus.

General Comments

There appeared to be little difficulty for most candidates to complete their answers in the allotted time. In general, candidates who did not complete the last question had also left earlier parts of questions unanswered.

The marks scored by candidates had a very wide range. There were some parts of questions that demanded little more than straightforward knowledge. Conversely, some sections were demanding. These required an ability to apply knowledge to different situations.

Candidates do need to realise that knowledge of the syllabus content is insufficient to score highly. They need to have an understanding of what they have learned and should be able to apply this knowledge to new situations.

Comments on Specific Questions

Question 1

Most candidates did appreciate that the expressions *density = mass/volume* and *weight = mass × acceleration of free fall* were required. In some situations, these expressions were not stated clearly. Some candidates were unfamiliar with the formula for the volume of a cylinder, even to the extent that the expression quoted was dimensionally unsound.

Candidates should always read the instructions carefully. In this question, credit was lost unnecessarily by some candidates who quoted the answer to more than two significant figures.

Question 2

(a) With few exceptions, the individual base units were quoted. Some answers were incorrect in that the algebra required to make *K* the subject of the expression was unsound.

(b) In general, the value of K was calculated correctly when the number of significant figures was not considered. Despite being provided with data for the individual percentage uncertainties, many answers gave an incorrect value for the total percentage uncertainty. Values of 3.5% and 4.0% were common.

For those candidates who did calculate the actual uncertainty correctly, the majority did not appear to appreciate how to present the final answer. The uncertainty should be given to one significant figure. This should be accompanied by the final answer quoted to the same decimal place as the uncertainty.

Question 3

(a) In any general definition, units should not be quoted. Furthermore, any ratio should be made clear.

(i) A response such as "rate of change of displacement" was required. Some candidates did not include a change in displacement, or referred to distance rather than displacement.

(ii) Similar shortcomings were evident in answers to this question, with references to speed rather than velocity being quite common.

(b) (i) Candidates were instructed to give reasons for their answers. Frequently, the answer was limited to a description of the magnitude of the velocity, without any reference to the evidence for any statements that is provided by the graph.

(ii) This was completed successfully by most candidates.

(iii) Some scripts did include clear working. In many others, it appeared that candidates had worked back from the answer given and, consequently, did not give any clear explanation as to how the velocity at time $t = 4.0\,\text{s}$ was determined.

(iv) This was completed successfully by most candidates. A minority used acceleration $9.81\,\text{m s}^{-2}$, rather than the value given in **(iii)**.

Question 4

(a) Elastic potential energy was usually explained satisfactorily in terms of energy stored in an object due to deformation. When considering gravitational potential energy, the majority made a reference to 'an object', rather than to energy stored in a mass.

(b) (i) **1.** This was generally completed without any problems. A minority did give the correct expression for kinetic energy but then substituted 16, rather than 16^2.

2. Again, this was generally completed successfully.

(ii) This proved to be difficult for the majority of candidates. In general, those who realised that the speed at time $\frac{1}{2}t$ would be $8.0\,\text{m s}^{-1}$ were successful. However, the great majority assumed, wrongly, that at time $\frac{1}{2}t$, the height would be one half of the maximum height.

(iii) The most common answer was to assume that air resistance would slow down the ball thus giving a longer time to reach the same maximum height. Few appreciated that air resistance would give rise to a greater retardation, thus leading to a shorter time before the ball comes to rest (at a reduced maximum height).

Question 5

(a) (i) **1.** This was generally satisfactory. The most usual shortcoming was an omission of a reference to either minimum distance or to neighbouring points.

2. The ratio needed to be made clear. A reference to "number of waves passing a point" is not sufficient.

(ii) It was common to find that this section was not attempted. What was required was a clear appreciation that, when substituting into the general expression for speed, the distance is the wavelength and that this distance is moved in the period T where $T = 1/f$.

(b) (i) Many candidates answered this successfully.

(ii) Although the majority did recognise that Fig. 5.1 included 3.75 wavelengths, it was not uncommon to find a value of 3.5 wavelengths given or even one wavelength.

(iii) There were many correct responses, in terms of either radians or degrees.

(c) The great majority of answers indicated that the ripple tank had not been studied in any detail.

Correct answers were in a minority. Many did not include a light source and screen. Rarely was there any means by which the movement of the waves could be 'frozen'.

Question 6

(a) In most answers, there was a satisfactory statement as regards energy losses in the internal resistance. Candidates should be encouraged not to refer to the energy 'overcoming' the internal resistance.

Very few answers included a satisfactory reference to the e.m.f. of the battery. It was expected that e.m.f. would be considered in terms of the total energy available (per unit charge).

(b) (i) This was completed successfully by the majority of candidates.

(ii) In a significant number of answers, there was no appreciation of *lost volts*. Successful candidates either calculated the *lost volts* or they applied Ohm's law to the complete circuit.

(c) (i) In general, a relevant expression for power was quoted. However, where this expression was given as $P = VI$, many substituted the terminal p.d. rather than the e.m.f. of the battery.

(ii) Most candidates did not use answers from previous calculations but, rather, they started afresh. The majority arrived at the correct conclusion.

Question 7

(a) (i) When completing such drawings, it is expected that reasonable care will be taken to ensure a true representation. In this situation, many lost credit because the lines were not equally spaced (judged 'by eye') or did not extend over the full region between the plates.

(ii) This was completed successfully by most candidates.

(b) (i) The answer was given and, consequently, very few candidates failed to arrive at the correct answer.

(ii) Most answers, and the unit, were correct. A minority confused the moment of one force with the torque of the couple.

(iii) This part of the question expected a statement and explanation. There were very few attempts at an explanation in terms of there being no resultant force and no resultant couple. Although the great majority of answers made reference to the end A moving upwards and the end B moving downwards, there were comparatively few clear statements that the rod would come to rest either 'vertical' or, more correctly, parallel to the electric field.

PHYSICS

Paper 9702/31

Advanced Practical Skills 1

Key Messages

- The Supervisor's Report and the sample set of results provided by each Centre form an important part of the marking process, and candidates may be disadvantaged if either is missing. The Supervisor's Report should include details of any difficulties or apparatus changes during the examination so that allowance can be made when marking. If help is provided to candidates, the Supervisor's Report **MUST** include candidate numbers and details of the assistance given.

- It is good practice to take readings which cover most of the experimental range available, and candidates should give some thought to the choice of values. For example, if it is possible to vary a particular length from 0 to 100 cm, then it is sensible to include readings for a maximum length over 90 cm and a minimum length under 10 cm.

- Normally a line of best fit should be fitted to all the points plotted on a graph. However, a candidate may sometimes wish to ignore one of their plotted points if it lies away from the general trend. This is acceptable as long as it is made clear that the point is being disregarded. If the point is labelled as anomalous, then credit can be given for fitting the line to the remaining points.

- To score highly on **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. General points such as "avoid parallax error" or "use more precise measuring instruments" will not usually gain credit without further detail.

General Comments

The general standard of the work done by the candidates was good and 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 candidates should be written down in the Supervisor's Report, and this report must be sent with the scripts to Cambridge 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 a 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. Most candidates were confident in the generation and handling of data but could improve by giving more thought to the critical evaluation of experiments.

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) Many candidates measured the diameter *d* within range and recorded it with consistent units. The most common errors were in the reading of the micrometer screw gauge (0.77 mm instead of 0.27 mm) or giving a value not consistent with the units (ranging from μm to km).

(c) (ii) Many candidates stated an appropriate V_1 and V_2. Other candidates needed to think whether their answer was realistic or not (i.e. 350 V or 350 mV from a 1.5 V power source) given that units were provided. The most common error was confusing mV with V leading to a power of ten error. A few candidates stated smaller values for V_1 compared to V_2 suggesting that the circuit was set up incorrectly.

(d) Many candidates were able to set up the experiment and collect six sets of values for l, V_1 and V_2. Some candidates collected data that suggested that just one distance, KL or LM, was equal to l instead of ensuring that both distances KL and LM were the same and equal to l. Some candidates did not set up the circuit with both resistors placed correctly.

Range and distribution of marks

(d) Many candidates did not extend the range of readings of l over at least 30.0 cm. Some candidates stated values of KL = LM which were greater than 50.0 cm, which is not possible as a metre rule was provided. Candidates should be encouraged to use as large a range as possible with the equipment provided.

Presentation of data and observations

Table

(d) Many candidates were able to include correct units with the column headings, including giving no units for the V_1/V_2 column heading. Some candidates incorrectly stated units for the V_1/V_2 column heading. A few candidates wrote the column headings l, V_1 or V_2 without a unit, or omitted a separating mark between the quantity and unit. Many candidates correctly stated the raw values of l to the nearest mm; others needed to take account of the precision of the metre rule, as they recorded answers to the nearest cm instead of to the nearest mm. Those candidates stating length in m often excluded the zero in the mm place, and did not gain credit (i.e. 0.3 m instead of 0.300 m). Stronger candidates were able to record the calculated quantity V_1/V_2 correctly and to the same number of significant figures as, or one more than, that used in the corresponding values of V_1 or V_2.

Graph

(e) (i) Candidates were required to plot a graph of V_1/V_2 against l. Many candidates gained credit for drawing appropriate axes with labels and sensible axes. Some candidates chose awkward scales that were either linear (going up in threes or sixes) or non-linear owing to gaps in the scale (missing out a number), and this resulted in errors in read-offs for the gradient and *y*-intercept calculations. Candidates can improve by checking that the first and last points, when plotted, extend over at least six large squares on the grid in the vertical direction and four large squares in the horizontal direction. Many candidates were able to gain credit for plotting the tabulated readings to within half a small square, a sharp pencil being essential. Candidates can improve by drawing finer points accurately on the grid to the nearest half a small square. Where candidates rounded their values in the table to one or two significant figures and plotted these points, they often lost credit for lack of quality of results.

(ii) Some candidates were able to draw a good line of best fit through six points. Few candidates gained credit for drawing a line through five trend points with one clear anomalous point identified. If a point is being treated as anomalous for the purposes of drawing the best line, this should be indicated clearly on the graph (it is recommended that any anomalous point be checked by repeating the measurement using the apparatus). Only one point, if any, should be identified as anomalous and not two or three.

Some candidates needed to rotate lines to give a better fit or move the line sideways to give a better balance of points along the entire length of the line. Others needed to draw a line of best fit that best represented all of the data. Common problems included choosing a few points that lie on a line, using the first and the last point to draw the line regardless of the distribution of the other points, or forcing the line through the origin regardless of the balance of points.

Analysis, conclusions and evaluation

Interpretation of graph

(e) (iii) Many candidates used a suitably large triangle to calculate the gradient, gaining credit for the read-offs, and substituted 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 the substitution clearly into $\Delta y/\Delta x$ (not $\Delta x/\Delta y$) and check that their triangle for calculating the gradient was large enough (the hypotenuse should be at least half the length of the line drawn and can be longer). Many triangles used were too small.

A few candidates drew a suitable triangle then proceeded to state different read-offs, either from the table or from different points on the graph that were not on the line of best fit. Some candidates read off the *y*-intercept at $x = 0$ directly from the graph, gaining credit. Others needed to check that the *x*-axis did actually start at $x = 0$ (i.e. no false origin) in order to validate this method. Many candidates substituted a read-off into $y=mx+c$ successfully to determine the *y*-intercept. Others needed to check that the point was actually on the line of best fit and not just a point from the table.

Drawing conclusions

(f) (i) Most candidates recognised that *P* was equal to the value of the gradient and *Q* was equal to the value of the intercept calculated in **(e)(iii)**. Others tried to calculate *P* and *Q* by first substituting values into the given equation and then solving simultaneous equations. No credit is given for this method as the question specifically asks for the answers in **(e)(iii)** to be used.

(ii) Some candidates stated their previous answers to (**a)(ii)** and **(f)(i)** to calculate a realistic value for ρ. Many candidates used inconsistent units and so the power of ten was often incorrect, i.e. candidates used cm instead of m or V instead of mV. A few candidates did not square the diameter in the area calculation so the value for ρ calculated was out of range.

Question 2

In this question, candidates were required to investigate a rubber band.

Successful collection of data

(b) Most candidates recorded a value of *m* with consistent units. A few candidates omitted units, whilst others quoted the mass in kg when it was clear that they meant g (e.g. 100 kg). If a candidate stated the mass in kg (e.g. 0.100 kg), then often the candidate did not give an appropriate number of decimal places to indicate the precision of the measurement. A mass recorded as 0.1 kg is not acceptable because it suggests a precision of 100 g rather than 1 g.

(c) (ii) Some candidates recorded a value of θ to the nearest degree and stated a unit. A few candidates stated θ to the nearest tenth of a degree or omitted the unit, and did not gain credit. Many candidates did not repeat the θ reading.

(d) (i) Most candidates correctly recorded a larger mass than originally used.

(ii) Nearly all candidates recorded a value of θ.

(e) Many candidates recorded a third value for θ that was close to the original value of θ when the slotted mass had been removed, gaining credit. A few candidates stated an angle of 180° (indicating the whole mass hanger was removed) or 0° (suggesting that the protractor was incorrectly read).

Quality

(e) Most candidates found that, the larger the mass of the load, the smaller the value of the angle subtended, gaining credit.

Presentation of data and observations

Display of calculation and reasoning

(c) (iv) Many candidates were able to calculate tan $\theta/2$. A few candidates incorrectly worked out (tan θ)/2. Although the calculation of $\tan^2(\theta/2)$ was not credited, many candidates found this calculation difficult and instead calculated $\tan(\tan^2\theta/2)$, $\tan(\theta/2)^2$ or $\tan(\theta/2)^{1/2}$, or the calculator was set in radian mode instead of degree mode.

(f) (i) The stronger candidates were able to calculate $k = m\tan^2(\theta/2)$ correctly for both experiments. A few candidates calculated $m / \tan^2\theta/2$ instead, and did not gain credit.

(ii) Few candidates were able to relate the number of significant figures in *k* to the significant figures used in *m* and θ. Other candidates related to just one quantity or to the "raw data" without specifying the quantities used, or to $\tan^2\theta/2$, $\tan\theta/2$ or "the quantity with the least number of significant figures" without stating the actual quantities involved.

Analysis, conclusions and evaluation

(f) (iii) Few candidates compared the percentage difference in their values of *k* by testing it against a specified percentage uncertainty, either taken from **(c)(iii)** or estimated themselves. Candidates should be encouraged to state what they think is a sensible limit for the percentage uncertainty for this particular experiment. Answers such as "the difference in the two *k* values is large/small" or "the *k* values were only 0.1 out" are insufficient.

Estimating uncertainties

(b) (iii) Most candidates were familiar with the equation for calculating percentage uncertainty, though few made a realistic estimate of the absolute uncertainty (2° – 5°). Most candidates stated the uncertainty as 1°, the smallest reading on the protractor, or less (0.1°). Candidates should recall that the absolute uncertainty in the value of θ depends not only on the precision of the measuring instrument being used but also on the nature of the experiment itself. In this particular experiment, the value of θ is difficult to judge as the rubber band and mass hanger could block the view of the centre point of the protractor. Where measurements have been repeated, an acceptable method to estimate the absolute uncertainty is to calculate half the range of the results obtained earlier and use this as the absolute uncertainty. When this method was used, some candidates forgot to halve the range.

Evaluation

(g) Many candidates found this section difficult. Most candidates were able to state that two readings were not enough and so more were needed and a graph should be plotted. The key to this section is for candidates to identify genuine problems associated with setting up this experiment and in obtaining readings. An answer such as "it is difficult to measure the angle" is insufficient to gain credit without an explanation. A much better answer would be "it is difficult to measure the angle θ because the rubber band was too thick and in the way of the protractor".

Candidates are encouraged to suggest detailed practical solutions that either improve technique or give more reliable data. They can improve their answers by stating the actual difficulties encountered during the experiment, e.g. parallax error in the angle measurement or difficulty in locating the centre of the band. They can also improve their answers by stating the methods used for each solution, e.g. clamping the protractor. In doing this, candidates should look at how each solution helps and improves this particular experiment. Credit is not given for insufficient detail in procedures such as "use a more accurate protractor" or "use a robotic arm". Credit is also not given for suggesting to change to the equipment under investigation e.g. "change rubber band" or "use a thicker band" when it is this particular band that is being investigated.

Credit is not given for suggestions that should be carried out anyway. Such suggestions include repeating measurements and calculating averages, avoiding parallax errors by looking at the protractor 'square on', checking the balance for zero errors or waiting for the mass to settle. General statements such as "turn fans off", "use an assistant", "scales not easy to read", "materials damaged" or "errors in calculation" do not usually gain credit. Candidates are not required to provide safety precautions so "use a bucket of sand to catch falling weights" does not gain credit.

A table giving details of limitations and potential improvements can be found in the mark scheme, together with some answers that did not receive credit.

PHYSICS

Paper 9702/33

Advanced Practical Skills 1

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Presentation of data and observations

Display of calculation and reasoning

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Analysis, conclusions and evaluation

(f) (iii) Few candidates compared the percentage difference in their values of k by testing it against a specified percentage uncertainty, either taken from **(c)(iii)** or estimated themselves. Candidates should be encouraged to state what they think is a sensible limit for the percentage uncertainty for this particular experiment. Answers such as "the difference in the two k values is large/small" or "the k values were only 0.1 out" are insufficient.

Estimating uncertainties

(b) (iii) Most candidates were familiar with the equation for calculating percentage uncertainty, though few made a realistic estimate of the absolute uncertainty (2° – 5°). Most candidates stated the uncertainty as 1°, the smallest reading on the protractor, or less (0.1°). Candidates should recall that the absolute uncertainty in the value of θ depends not only on the precision of the measuring instrument being used but also on the nature of the experiment itself. In this particular experiment, the value of θ is difficult to judge as the rubber band and mass hanger could block the view of the centre point of the protractor. Where measurements have been repeated, an acceptable method to estimate the absolute uncertainty is to calculate half the range of the results obtained earlier and use this as the absolute uncertainty. When this method was used, some candidates forgot to halve the range.

Evaluation

(g) Many candidates found this section difficult. Most candidates were able to state that two readings were not enough and so more were needed and a graph should be plotted. The key to this section is for candidates to identify genuine problems associated with setting up this experiment and in obtaining readings. An answer such as "it is difficult to measure the angle" is insufficient to gain credit without an explanation. A much better answer would be "it is difficult to measure the angle θ because the rubber band was too thick and in the way of the protractor".

Candidates are encouraged to suggest detailed practical solutions that either improve technique or give more reliable data. They can improve their answers by stating the actual difficulties encountered during the experiment, e.g. parallax error in the angle measurement or difficulty in locating the centre of the band. They can also improve their answers by stating the methods used for each solution, e.g. clamping the protractor. In doing this, candidates should look at how each solution helps and improves this particular experiment. Credit is not given for insufficient detail in procedures such as "use a more accurate protractor" or "use a robotic arm". Credit is also not given for suggesting to change to the equipment under investigation e.g. "change rubber band" or "use a thicker band" when it is this particular band that is being investigated.

Credit is not given for suggestions that should be carried out anyway. Such suggestions include repeating measurements and calculating averages, avoiding parallax errors by looking at the protractor 'square on', checking the balance for zero errors or waiting for the mass to settle. General statements such as "turn fans off", "use an assistant", "scales not easy to read", "materials damaged" or "errors in calculation" do not usually gain credit. Candidates are not required to provide safety precautions so "use a bucket of sand to catch falling weights" does not gain credit.

A table giving details of limitations and potential improvements can be found in the mark scheme, together with some answers that did not receive credit.

PHYSICS

Paper 9702/34

Advanced Practical Skills 2

Key Messages

- The Supervisor's Report and the sample set of results provided by each Centre form an important part of the marking process, and candidates may be disadvantaged if either is missing. The Supervisor's Report should include details of any difficulties or apparatus changes during the examination so that allowance can be made when marking. If help is provided to candidates, the Supervisor's Report **MUST** include candidate numbers and details of the assistance given.

- It is good practice to take readings which cover most of the experimental range available, and candidates should give some thought to the choice of values. For example, if it is possible to vary a particular length from 0 to 100 cm, then it is sensible to include readings for a maximum length over 90 cm and a minimum length under 10 cm.

- Normally a line of best fit should be fitted to all the points plotted on a graph. However, a candidate may sometimes wish to ignore one of their plotted points if it lies away from the general trend. This is acceptable as long as it is made clear that the point is being disregarded. If the point is labelled as anomalous, then credit can be given for fitting the line to the remaining points.

- To score highly on **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. General points such as "avoid parallax error" or "use more precise measuring instruments" will not usually gain credit without further detail.

General Comments

Centres reported few problems with providing the necessary apparatus for the two questions. Where apparatus had to be varied slightly (e.g. some washer sizes), and it was recorded in the Supervisor's Report, Examiners were able to take this into account

The majority of candidates had time to complete both questions. In many cases Centres had prepared their candidates well after referring to mark schemes from previous papers. These candidates knew what was expected in the presentation and analysis of graphs, and in the discussion of experimental procedures. Many achieved high marks in both questions.

Comments on Specific Questions

Question 1

In this question, candidates were required to investigate the forces on a wooden strip as the position of a position of a suspended mass was changed.

Successful collection of data

(a) (ii) Most answers included a unit with the value for h_2.

(b) (iv) Most candidates measured recorded values of L_A and L_B (the spring lengths) which differed in the expected way. In some cases, however, the values suggested that the suspended mass had not been positioned correctly, or had been omitted altogether.

(c) Nearly every candidate recorded results for six different values of x. Examiners looked for a correct change in L_A as x changed, but a few candidates' x values were so close together that L_A remained the same.

Range and distribution of values

(c) The apparatus allowed for x to vary from 0 cm to 100 cm. Candidates tended to group their readings near to one end of this range, and very few spread out their values enough to include both large and small lengths.

Table

(c) Tables were generally neat and well-organised. In good answers, the headings included units separated from their quantity by using a solidus (/) or by using brackets. A few candidates missed out the unit for $(L_A - L_B)$, and some gave a unit for the ratio $(L_A - L_B)/C$.

Stronger candidates correctly recorded all their values of x to the nearest mm. Even when the candidate can choose a value in whole cm it should be recorded to the precision available, e.g. 10.0 cm. Weaker candidates often added an extra zero to all readings, e.g. 20.00 cm.

Calculations were nearly always done well. In a small number of cases, too few significant figures were given for a calculated value because a significant zero was dropped from the end, e.g. 3 instead of the correct 3.0.

Graph

(d) (i) There were many good graphs with simple, clearly labelled scales and with all points from the table clearly and accurately plotted.

There were few graphs where points were plotted as dots that were too big (over 1 mm in diameter).

There were some cases of awkward scales (e.g. 0, 15, 30, 45 cm etc.) and even some for which the candidate had just divided his/her range by 8 (e.g. 20, 26.25, 32.5, 38.75 cm etc.). Although this may make the points fill more of the graph grid, it makes plotting much more difficult and mistakes more likely.

The quality of results (as judged by scatter on the graph) was often excellent.

(ii) Drawn lines were usually clearly defined, and some candidates sensibly circled an outlying point to show that they were ignoring it when choosing their line. Weaker candidates tended to join the first and last points rather than position their line as closely as possible to all points to indicate the overall trend.

Interpretation of graph

(d) (iii) Most Centres had prepared candidates well. In good answers, a triangle indicated the coordinates used to calculate the gradient, with the calculation itself presented in full. In a few cases credit was lost because the triangle was too small.

For this experiment the y-intercept could usually be read directly from the $(L_A–L_B)/C$ axis, although a significant number of candidates mistakenly did this where there was a false origin (i.e. the x-axis scale did not start from zero).

Drawing conclusions

(e) The majority of candidates identified the values of the constants a and b as their gradient and intercept values, including any negative sign.

Not all candidates included a correct unit for a (often cm instead of cm^{-1}), and some mistakenly gave a unit for the dimensionless b.

Question 2

In this question, candidates were required to investigate the equilibrium position of a spool of thread. The experiment required patience, but most candidates made the required measurements. Candidates from many Centres had difficulty reading vernier calipers.

Successful collection of data

(a) (i) Measuring spool diameters was not well done in general, with many errors involving powers of ten. For example, 12.3 mm was often recorded as 1.23 mm. Overall, candidates' values given for d ranged from more than 100 mm to less than 0.1 mm. It is important that candidates have practice in converting between the various multiples, and they should also be able to estimate a measurement so they can ask themselves "how big is this diameter?" and "is my value sensible?"

(d) (iv) The measurement of the equilibrium angle θ needed care and perseverance. Many candidates recorded angles outside the expected range, sometimes greater than 90° (suggesting that the wrong scale on the protractor was being used). Some values were also given to 0.1° rather than the 1° precision of their protractor. Only the more able candidates recorded all their values from repeated measurements, then calculated an average.

(f) Most candidates repeated the experiment using the second spool, but often their results did not show the correct trend of angle with diameter.

Estimating uncertainties

(e) When the spool reached its equilibrium position the angle tended to vary slightly as the thread continued to be pulled, so there was some uncertainty in the angle measurement. Good candidates recognised this and went on to use an uncertainty of 2° or more in their percentage uncertainty calculation, often determined from the scatter in their repeated readings of the angle. Weaker candidates just used the 1° precision of their protractor, which was much too optimistic in this experiment.

Display of calculation and reasoning

(a) (ii) The calculation of R was well done, with very few making a rounding error when recording the value.

(b) There were many very good explanations for the number of significant figures for R. A few candidates discussed decimal places instead of s.f., and some talked of "raw data" rather than specifying the quantities used in the calculation (i.e. D and d).

(g) (i) Most candidates successfully calculated two values for the constant k. Only a few made mistakes when rearranging the equation or when transferring values into their formula.

Conclusions

(g) (ii) Candidates from well-prepared Centres produced a clearly-reasoned conclusion based on their two k values. They looked at the relative difference between the two values (i.e. the percentage difference) and looked at whether it fell within a (stated) percentage variation that they felt was reasonable for this experiment. Weaker candidates only decided whether the difference between k values was "large" or "small".

Evaluation

(h) Although the experiment was not easy to carry out, it provided plenty of scope for candidates to describe the difficulties that they had encountered, and to suggest improvements. Some Centres had used previous mark schemes to show candidates how to name a difficulty and identify the cause (e.g. "it was difficult to measure the angle because it varied with time"), and to describe an improvement with enough practical detail (e.g. "video the experiment and then measure the angle from a still image of a frame"). Many of these candidates were able to make short, concise statements that scored high marks.

The problem with making the spool roll straight was identified by most candidates, and many went on to suggest using a rule on each side to make a straight track.

The issue of parallax (because of the distance between the thread and the protractor) was also widely recognised, and some candidates suggested pulling the thread over a guide so that it was next to the protractor.

Many candidates also listed the difficulty in ensuring that the protractor was vertical. They usually went on to suggest using a rule and set square, but only a few described how they would be used.

The published mark scheme gives further detail of acceptable improvements.

PHYSICS

Paper 9702/35

Advanced Practical Skills 1

Key Messages

- The Supervisor's Report and the sample set of results provided by each Centre form an important part of the marking process, and candidates may be disadvantaged if either is missing. The Supervisor's Report should include details of any difficulties or apparatus changes during the examination so that allowance can be made when marking. If help is provided to candidates, the Supervisor's Report **MUST** include candidate numbers and details of the assistance given.

- It is good practice to take readings which cover most of the experimental range available, and candidates should give some thought to the choice of values. For example, if it is possible to vary a particular length from 0 to 100 cm, then it is sensible to include readings for a maximum length over 90 cm and a minimum length under 10 cm.

- Normally a line of best fit should be fitted to all the points plotted on a graph. However, a candidate may sometimes wish to ignore one of their plotted points if it lies away from the general trend. This is acceptable as long as it is made clear that the point is being disregarded. If the point is labelled as anomalous, then credit can be given for fitting the line to the remaining points.

- To score highly on **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. General points such as "avoid parallax error" or "use more precise measuring instruments" will not usually gain credit without further detail.

General Comments

The general standard of the work done by the candidates was good and 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 candidates should be written down in the Supervisor's Report, and this report must be sent with the scripts to Cambridge 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 a 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. Most candidates were confident in the generation and handling of data but could improve by giving more thought to the critical evaluation of experiments.

There were no common misinterpretations of the rubric.

Comments on Specific Questions

Question 1

In this question, candidates were asked to investigate the motion of a swinging bob and a wooden rod.

Successful collection of data

(a) Most candidates correctly recorded a value for L in the range 0.500 m – 0.600 m. A few candidates recorded their answers in cm or mm without changing the unit already given on the paper.

(c) (iv) Most candidates recorded a value for n in the range 3 – 8. A few candidates interpreted half-swings as complete to-and-fro swings, obtaining answers that were out of range. Candidates should be encouraged to read the instructions carefully, even for question parts such as **(c)(i)**, **(c)(ii)** and **(c)(iii)** that do not carry marks.

(d) Almost all candidates were able to set up the experiment without assistance, and collect six sets of values of D, x and n showing the correct trend (n increasing as D decreased). A few candidates lost credit because they measured the time for n swings rather than counting them.

Range and distribution of data

(d) Most candidates recorded a suitable range of values for D. Some candidates could have made better use of the available range of values, needing at least one value greater than 50 cm and at least one value less than 45 cm. A few candidates ignored the instruction to only consider values of D greater than or equal to 40 cm, so lost this mark. These candidates tended to lose further credit for the poor quality of their results, because below this value the trend is reversed i.e. n decreases as D decreases.

Presentation of data and observations

Table

(d) Most candidates were awarded the mark for using the correct column headings in their tables, giving both the quantity recorded and suitable units for each quantity, with the two separated by a solidus, or the units in brackets. A few candidates recorded units for n or $((n+1)/n)^2$, so lost this mark. The majority of candidates gave the raw values for D to the nearest mm; others needed to take account of the precision of the metre rule, recording answers to the nearest mm rather than the nearest cm. Most expressed the value of $((n+1)/n)^2$ to 2 or 3 significant figures and the great majority calculated these values correctly.

Graph

(e) (i) Candidates were required to plot a graph of $((n+1)/n)^2$ against x. Most candidates gained credit for drawing appropriate axes, with labels and sensible scales, though some had compressed scales on the y-axis, with points occupying less than six large squares in the y-direction. Others chose difficult or awkward scales (these candidates often lost marks for incorrect plotting of points or incorrect read-offs when calculating the gradient or intercept). Many candidates gained credit for plotting their tabulated readings correctly, indicating any anomalous point; others needed to draw the plotted points so that the diameters were equal to, or less than, half a small square. Some candidates can improve by plotting the points more accurately i.e. to within half a small square.

(ii) Some candidates were able to draw carefully considered lines of best fit, but many joined the first and last points on the graph regardless of the distribution of the other points. There should always be a balanced distribution of points either side of the line. Any anomalous point (that has been ignored when drawing the line of best fit) should be clearly labelled or ringed.

Analysis, conclusions and evaluation

Interpretation of graph

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

Some candidates correctly read off the y-intercept at $x = 0$ directly from the graph. Others needed to check that the x-axis started with $x = 0$ (i.e. no false origin) for this method of finding the intercept

to be valid. Several candidates correctly substituted a read-off into $y=mx+c$ to determine the y-intercept. Others needed to check the point chosen was actually on the line drawn and not just in the table.

Drawing conclusions

(f) Most candidates recognised that $-P$ was equal to the value of the gradient and Q was equal to the value of the intercept calculated in **(e)(iii)**, though some candidates overlooked the change in sign to find P. A few candidates tried to calculate P and Q by first substituting values into the given equation and then solving simultaneous equations. No credit is given for this as the question specifically asks for the answers in **(e)(iii)** to be used to determine P and Q.

Fewer candidates recorded the correct units for P and Q. Common mistakes were to record the units for P as m or cm rather than m^{-1} or cm^{-1}, or to omit the units for P completely.

Question 2

In this question, candidates were required to investigate the motion of a water-filled ball in a container of water.

Successful collection of data

(b) (i) Most candidates recorded a value for V_0 in the range 25.0 to 35.0 cm^3.

(ii) The majority of candidates stated that they had added the individual volumes together to find V_0; others simply described what they had done, and did not receive credit.

(c) (iii) Almost all candidates recorded a value for the distance x between the rubber bands, though some needed to repeat their measurements for the second mark.

(d) (ii) Most candidates recorded second values for V and x.

Quality

(d) (ii) Almost all candidates found that the first value of x (for the heavier ball) was greater than the second value, and were awarded this mark.

Display of calculation and reasoning

(b) (v) Almost all candidates were able to calculate V correctly, by subtracting 5 cm^3 from their value for V_0 in **(b)(i)**.

(e) (i) The great majority of candidates were able to calculate k for the two sets of data, showing their working clearly. A few candidates calculated V^3/x, or x/V for the value of k so were not awarded this mark.

(e) (ii) Some candidates were able to justify the significant figures they had given for the values of k correctly, linking the significant figures for k explicitly to D and V. Others made reference to V^3 rather than V, or simply referred to the "raw data", so could not be awarded this mark.

Analysis, conclusions and evaluation

(e) (iii) Most candidates calculated the percentage difference between their two values of k, and then tested it against a specified percentage uncertainty, either taken from **(b)(vi)** or estimated themselves. Some candidates gave answers such as "the difference in the two k values is very large/quite small" which is insufficient for this mark – a numerical comparison is required here.

Estimating uncertainties

(b) (vi) Most candidates were familiar with the equation for calculating percentage uncertainty, though many made too small an estimate of the absolute uncertainty in the value of V. A common error was to state the uncertainty as simply the smallest scale division on the syringe (usually 0.5 ml).

Candidates should remember that the absolute uncertainty in the value of *V* depends not only on the precision of the measuring instrument being used but also on the nature of the experiment itself.

Evaluation

(f) Many candidates recognised that two sets of data were insufficient to draw a valid conclusion and suggested repeating the experiment for other values of *V* and then plotting a suitable graph. Some recognised the difficulty in removing the correct amount of water as air was also drawn into the syringe, and suggested sensible improvements such as using a syringe with a longer nozzle or needle attached, so that no air was withdrawn. Many candidates identified some of the difficulties in recording the lowest depth accurately, but their answers needed to be expressed more precisely. Answers such as "the ball moved too fast" were not given credit; answers such as "the ball was at rest/at its lowest depth for a short time" were needed.

A few candidates identified the large uncertainty in the value of *V* because of the large scale divisions on the syringe and suggested using a syringe with smaller scale divisions/greater precision, though some candidates confused precision with accuracy.

The key to this section is for candidates to identify genuine problems associated with setting up this experiment and in obtaining readings. Candidates are encouraged to suggest detailed practical solutions that either improve technique or give more reliable data. For example, many candidates suggested videoing the experiment and then playing the experiment back frame-by-frame, but only a few stated that a scale/ruler should be included in order to measure *x*.

Credit is not given for suggestions that could be carried out in the original experiment, such as repeating measurements or avoiding parallax errors by looking at an instrument at eye level. Vague answers such as "systematic error" or "use an assistant" are not usually given credit.

A table giving details of limitations and potential improvements can be found in the published mark scheme, together with some answers that did not receive credit.

PHYSICS

Paper 9702/36

Advanced Practical Skills 2

Key Messages

- The Supervisor's Report and the sample set of results provided by each Centre form an important part of the marking process, and candidates may be disadvantaged if either is missing. The Supervisor's Report should include details of any difficulties or apparatus changes during the examination so that allowance can be made when marking. If help is provided to candidates, the Supervisor's Report **MUST** include candidate numbers and details of the assistance given.

- It is good practice to take readings which cover most of the experimental range available, and candidates should give some thought to the choice of values. For example, if it is possible to vary a particular length from 0 to 100 cm, then it is sensible to include readings for a maximum length over 90 cm and a minimum length under 10 cm.

- Normally a line of best fit should be fitted to all the points plotted on a graph. However, a candidate may sometimes wish to ignore one of their plotted points if it lies away from the general trend. This is acceptable as long as it is made clear that the point is being disregarded. If the point is labelled as anomalous, then credit can be given for fitting the line to the remaining points.

- To score highly on **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. General points such as "avoid parallax error" or "use more precise measuring instruments" will not usually gain credit without further detail.

General Comments

Centres reported few problems with providing the necessary apparatus for the two questions.

The majority of candidates had time to complete both questions, and in most cases the instructions were understood and followed carefully. In many cases Centres had prepared their candidates well after referring to mark schemes from previous papers. These candidates knew what was expected in the presentation and analysis of graphs, and in the discussion of experimental procedures. Many achieved high marks in both questions.

Comments on Specific Questions

Question 1

In this question, candidates were required to assemble an electrical circuit and then measure the potential difference between various points.

Supervisor's reports indicated that very few candidates were given help with the circuit.

Successful collection of data

(b) (i) Most answers included a sensible initial value and unit for E.

(c) (iii) Several candidates recorded a value of x of 0.5 m, rather than the expected 0.3 m. Even if this was due to an incorrectly connected circuit, it was still possible to obtain full credit in the remainder of the question.

(d) Nearly all candidates recorded results for six different values of x, in most cases with V changing consistently as x changed.

Range and distribution of values

(d) The apparatus allowed for x to vary from 0 cm to 100 cm. Candidates tended to group their readings near to one end of this range, and very few spread out their values enough to include both large and small lengths.

Table

(d) Tables were generally neat and well-organised. In good answers the headings included units separated from their quantity by using a solidus (/) or by using brackets. A few candidates missed out the unit for V, and some gave the unit for V/E as (V/V) instead of no unit.

Stronger candidates correctly recorded all their values of x to the nearest mm. Even when the candidate can choose a value in whole cm it should be recorded to the precision available, e.g. 10.0 cm. Weaker candidates often added an extra zero to all readings, e.g. 21.00 cm.

Calculations were usually done well, although some candidates calculated V/x rather than V/E. In several cases too few significant figures were given – if both V and E have 4 s.f. then V/E should have 4 or 5 s.f.

Graph

(e) (i) There were many good graphs with simple, clearly labelled scales and with all points from the table clearly and accurately plotted.

In a few cases the points were plotted as dots that were too big (over 1 mm in diameter) – it is better to use a sharp pencil to indicate a point with a small cross for precise coordinates.

There were only a few cases of awkward scales (e.g. 0, 15, 30, 45 cm etc.). Although this may make the points fill more of the graph grid it makes plotting more difficult and mistakes more likely.

The quality of results (as judged by scatter on the graph) was often excellent.

(ii) Drawn lines were usually clearly defined, and some candidates sensibly circled an outlying point to show that they were ignoring it when choosing their line.

Interpretation of graph

(e) (iii) Most Centres had prepared candidates well. In good answers, a triangle indicated the coordinates used to calculate the gradient, with the calculation itself presented in full. In a few cases credit was lost because the triangle was too small.

For this experiment the y-intercept could usually be read directly from the V/E axis, although a small number of candidates mistakenly did this where there was a false origin (i.e. the x-axis scale did not start from zero).

Drawing conclusions

(d) The majority of candidates identified the values of the constants a and b as their gradient and intercept values, with their value for b in the expected range.

Not all candidates included a unit for a (b should not have a unit). In a few cases the unit for a did not correspond to the units used earlier in the experiment (e.g. a was given as 0.0142 m^{-1} instead of 0.0142 cm^{-1}).

Question 2

In this question, candidates were required to investigate collisions between spheres rolling on a track.

Successful collection of data

(a) (i) Most candidates recorded masses for their spheres, and most were in the expected range. A few candidates added an unnecessary zero to some values, presumably to maintain the same number of significant figures (e.g. 20.6 g and 5.90 g). This was incorrect as readings should be recorded to the precision available (to the nearest 0.1 g in this case), so all values of mass should have been to the same number of decimal places.

(b) Most candidates recorded a sensible value for h_0, although several used incorrect precision (e.g. 20.00 cm instead of 20.0 cm).

(c) Most candidates showed that they had carried out repeats by recording all of their readings for h_B before finding the average.

(e) Nearly all candidates got the expected result of a smaller h_B for a larger sphere.

Estimating uncertainties

(d) When asked to measure the rise height h_B of the sphere, stronger candidates realised that the uncertainty was greater than the 1 mm precision of their rule. They either used half the range of their repeats, or estimated an uncertainty between 2 and 5 mm. In a few cases mixed units (cm and mm) were used in the calculation of the percentage.

Display of calculation and reasoning

(a) (iii) In most cases the candidate correctly calculated the value for R, and made no rounding error in the final value.

(a) (iv) A large number candidates explained clearly that the significant figures given for R depended on the s.f. in both m_A and m_B. Others referred only to "raw data", or discussed decimal places instead of significant figures.

(f) (i) Most candidates successfully calculated two values for the constant k. Only a few made mistakes when rearranging the equation or when transferring values into their formula.

Conclusions

(f) (ii) Candidates from well-prepared Centres produced a clearly-reasoned conclusion based on their two k values. They looked at the relative difference between the two values (i.e. the percentage difference) and looked at whether it fell within a (stated) percentage variation that they felt was reasonable for this experiment. Weaker answers only decided whether the difference between k values was "large" or "small".

Evaluation

(g) Some Centres had used previous mark schemes to show candidates how to name a difficulty and identify the cause (e.g. "it was difficult to measure to the bottom of the sphere because it was hidden by the sides of the track"), and to describe an improvement with enough practical detail (e.g. "measure to bottom of track and add on the thickness of the track"). Many of these candidates were able to make short, concise statements that scored high marks.

The main experimental difficulties concerned measuring h_B. There was a likelihood of parallax error because the rule could not be positioned right next to the sphere. In addition, the sphere was only at its maximum for an instant so it was difficult to judge the height (weaker candidates just said it "moved too fast"). Many candidates suggested a video recording of the sphere, but not all of them included a measuring scale in the picture.

Other difficulties identified included making sure that the rule was vertical, and releasing the sphere without exerting a force on it. Stronger answers went on to describe practical solutions.

A few candidates suggested that the results would be affected by friction, though no workable solutions to this problem were described.
The published mark scheme gives further detail of acceptable improvements.

PHYSICS

Paper 9702/41
A2 Structured Questions

Key Messages

- Candidates should be encouraged to read the command words used in each question carefully. "State and explain" indicates that an explanation is a required part of the answer. Candidates often lose credit for this type of question when they provide only a statement without an explanation.
- An important aspect of the assessment in this component is the ability to show understanding and to apply knowledge to unfamiliar situations. Candidates do, in general, require more experience of questions where these skills are being assessed.
- Candidates should explain their work fully. In particular, relevant formulae should be quoted and full substitution of values made clear. Candidates should be reminded that they may lose credit where working is not shown clearly.

General Comments

With very few exceptions, well-prepared candidates had sufficient time to complete their answers. Some candidates did not complete the final parts of **Question 12** but, invariably, there were parts of earlier questions that had not been attempted.

The marks scored by candidates ranged widely. Some candidates are to be congratulated on the level of their preparation. Unfortunately, there also many candidates who would have benefited from greater knowledge of the relevant physics.

Comments on Specific Questions

Section A

Question 1

(a) Candidates should be reminded that potential is defined in terms of the work that is done on the unit mass when it is moved from infinity.

(b) (i) The answer to this part was provided. Therefore, the credit was given for a clear statement of the situation and then substitution of numerical values. In many scripts, a clear initial statement was not provided. In "show that" questions it is essential that the candidates make clear the starting point of their working.

(ii) An initial statement in terms of *changes* in energy was expected. Frequently, a written statement was omitted.

(c) There were some correct responses based on the fact that the Earth would attract the rock. It was rare to find an answer based on the effect of the Earth's potential. Many candidates made a comparison of the Moon and the Earth, based on these two being isolated in space.

Question 2

(a) (i) This was generally answered correctly in terms of the number of molecules, although there were some references to number of moles.

(ii) There was some confusion between mean-square speed, square of the mean speed and root-mean-square speed.

(b) This was generally completed successfully, although a significant minority gave very little evidence of the algebraic and arithmetical manipulation.

(c) (i) Candidates found this part difficult. It was common to find that the answer given was for one molecule. That is, the factor based on the Avogadro constant had been omitted. Candidates should be encouraged to carry out a quick mental check on the magnitude of their answers, and they could then have realised that the answer given was unrealistic.

(ii) There were some correct answers based on the fact that work has to be done by the gas against the external pressure. Many thought that no energy would be required because the final temperature would not be different in the two situations.

Question 3

(a) (i) The answer was correct in the great majority of scripts.

(ii) A minority of candidates calculated a gradient from the graph. Most used the expression $v = \omega x$ and arrived at the correct answer.

(b) (i) For most sketches, it was realised that the curve would be the inverse of that for E_P. However, many were drawn very roughly, without showing smooth curves. Also many showed little regard as to where the lines for E_P and E_K should intersect.

(ii) Correct answers were rare. It would have helped candidates to realise that, at maximum amplitude, the potential energy is equal to the total energy of the oscillation.

Question 4

(a) (i) Candidates should be reminded that the law applies to point charges.

(ii) Most candidates did give a correct expression for the force. A common mistake was to write the product of the charges as either $2e$ or e^2.

(b) (i) The majority did make a clear reference to the ratio, and many included positive charge. Very few mentioned that the charge should be stationary.

(ii) 1. The most straightforward explanation is based on the fact that electric field is a vector quantity and that the two charges would repel one another. In some scripts, the difference in sign was incorrectly attributed to either the proton or the α-particle having a negative charge.

2. There were some sketches that had been drawn with care. Many others realised that the line would lie between the given lines but they either did not realise, or did not draw with sufficient care, where the line should be.

Question 5

(a) (i) In general the direction was shown correctly, although a significant minority showed the field entering the solenoid at both ends.

(ii) This was answered correctly in most scripts.

(b) Many candidates gave an incorrect explanation in terms of the Hall probe cutting the lines of magnetic flux, and this reveals a misconception about the operation of the Hall probe. Very few answers made reference to the fact that the Hall voltage is dependent on the angle between the plane of the probe and the magnetic field.

(c) (i) This was generally answered correctly, although the use of the term *electromagnetic force* rather than *electromotive force* is common.

(ii) The majority of candidates could give two different ways. Candidates should be advised to ensure that their suggestions are different in nature. Moving the coil towards the solenoid and moving the coil away from the solenoid are not considered as being two different ways.

Question 6

(a) Candidates found this explanation challenging. Most were based, simply, on the force in the magnetic field providing the centripetal force. Many stated that the force would be normal to the magnetic field, rather than the direction of motion. Very few stated that the force would have a constant magnitude.

(b) With few exceptions, the derivation was acceptable.

(c) (i) Apart from occasional arithmetical errors, the calculation caused very few problems.

(ii) Candidates should realise that any line should show the main features. Many rough sketches were drawn with a varying radius within the region of the field. The path on entering and leaving the region of the field should be a tangent to the curved path. Often the path was drawn with a pronounced kink.

Question 7

(a) Most explanations were based on the fact that the observed pattern provides evidence of diffraction. This was then related to diffraction of waves.

(b) Many answers were restricted to a statement that the wavelength and hence the radii would decrease. There were comparatively few explanations based on increased momentum and giving the de Broglie relation.

(c) The majority of derivations were based on an incorrect assumption. Rather than determine momentum based on the premise that the energies of the particles are equal, candidates assumed that the speeds of the particles would be identical.

Question 8

(a) This was generally satisfactory although there was confusion between the terms *nucleus*, *nucleon*, *neutron* and *nuclide*.

(b) (i) With few exceptions, the reaction was named correctly.

(ii) Reference to the nucleon numbers shown in the reaction should have provided a very clear indication as to the positions. It was not uncommon to have the nuclei in an incorrect order. Others showed all three nuclei to the left of the peak.

(iii) 1. A significant number of answers were incorrect through errors other than arithmetical. Some candidates did not include all of the particles in their calculations.

2. It was expected that candidates would use the expression $E = c^2 \Delta m$ and then convert energy in joules to MeV. Some candidates gave a figure, correctly or incorrectly, for the number of MeV equivalent to 1.0 u. The correct number for the calculation, based on three significant figures, was accepted.

Section B

Question 9

(a) Candidates should avoid paraphrasing the question. Some explanation, other than saying that data from the sensing device is processed, was expected.

(b) Many candidates found it difficult to draw a correct circuit. In many, the resistor and the thermistor were not drawn as being in series between the 4 V line and earth.

(c) Few candidates could give two reasons. A common answer was to state that the relay could be used to switch large currents, without making any reference to the small current that gives rise to this switching.

Question 10

(a) Fewer candidates this series confused ultrasound with either X-rays or MRI.

Candidates do need to emphasise that the ultrasound is pulsed and that the pulses are partially reflected at boundaries.

(b) There were comparatively few answers based on shorter wavelength giving better resolution. Most referred to penetrating power or health risks.

(c) (i) For those candidates who could recall the relevant expression, the calculation presented few problems.

(ii) There were some good answers but many did not account for the greater attenuation as a consequence of the pulses travelling through a greater thickness of tissue and crossing more boundaries.

Question 11

(a) Many underlined the whole of one of the numbers near the centre of Fig. 11.2. Candidates would benefit from further practice at questions on analogue-to-digital conversion.

(b) Some answers were correct but candidates would benefit from further study of this area.

(c) Many answers consisted of a statement, with frequency either too high or too low, without justification. Others quoted Nyquist but, again, any conclusion was not substantiated. Comparatively few made any reference to detail of changes in *V* between the times at which the samplings took place.

Question 12

(a) There were some convincing answers, but in many it was not made clear as to why the logarithmic scale would be more appropriate.

(b) (i) There appeared to be a considerable amount of guesswork which included suggestions such as ‘AM’ and ‘wireless’.

(ii) With few exceptions, a correct expression for attenuation/dB was quoted. The usual problem was associated with the ratio of the two powers and the sign obtained when the logarithm is calculated. In some answers, a negative sign either disappeared or was ignored, without any explanation.

PHYSICS

Paper 9702/42
A2 Structured Questions

Key Messages

- Candidates should be encouraged to read the command words used in each question carefully. "State and explain" indicates that an explanation is a required part of the answer. Candidates often lose credit for this type of question when they provide only a statement without an explanation.
- An important aspect of the assessment in this component is the ability to show understanding and to apply knowledge to unfamiliar situations. Candidates do, in general, require more experience of questions where these skills are being assessed.
- Candidates should explain their work fully. In particular, relevant formulae should be quoted and full substitution of values made clear. Candidates should be reminded that they may lose credit where working is not shown clearly.

General Comments

With very few exceptions, well-prepared candidates had sufficient time to complete their answers. Some candidates did not complete the final parts of **Question 12** but, invariably, there were parts of earlier questions that had not been attempted.

The marks scored by candidates ranged widely. Some candidates are to be congratulated on the level of their preparation. Unfortunately, there also many candidates who would have benefited from greater knowledge of the relevant physics.

Comments on Specific Questions

Section A

Question 1

(a) Candidates should be reminded that potential is defined in terms of the work that is done on the unit mass when it is moved from infinity.

(b) (i) The answer to this part was provided. Therefore, the credit was given for a clear statement of the situation and then substitution of numerical values. In many scripts, a clear initial statement was not provided. In "show that" questions it is essential that the candidates make clear the starting point of their working.

(ii) An initial statement in terms of *changes* in energy was expected. Frequently, a written statement was omitted.

(c) There were some correct responses based on the fact that the Earth would attract the rock. It was rare to find an answer based on the effect of the Earth's potential. Many candidates made a comparison of the Moon and the Earth, based on these two being isolated in space.

Question 2

(a) (i) This was generally answered correctly in terms of the number of molecules, although there were some references to number of moles.

(ii) There was some confusion between mean-square speed, square of the mean speed and root-mean-square speed.

(b) This was generally completed successfully, although a significant minority gave very little evidence of the algebraic and arithmetical manipulation.

(c) (i) Candidates found this part difficult. It was common to find that the answer given was for one molecule. That is, the factor based on the Avogadro constant had been omitted. Candidates should be encouraged to carry out a quick mental check on the magnitude of their answers, and they could then have realised that the answer given was unrealistic.

(ii) There were some correct answers based on the fact that work has to be done by the gas against the external pressure. Many thought that no energy would be required because the final temperature would not be different in the two situations.

Question 3

(a) (i) The answer was correct in the great majority of scripts.

(ii) A minority of candidates calculated a gradient from the graph. Most used the expression $v = \omega x$ and arrived at the correct answer.

(b) (i) For most sketches, it was realised that the curve would be the inverse of that for E_P. However, many were drawn very roughly, without showing smooth curves. Also many showed little regard as to where the lines for E_P and E_K should intersect.

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(ii) Most candidates did give a correct expression for the force. A common mistake was to write the product of the charges as either $2e$ or e^2.

(b) (i) The majority did make a clear reference to the ratio, and many included positive charge. Very few mentioned that the charge should be stationary.

(ii) 1. The most straightforward explanation is based on the fact that electric field is a vector quantity and that the two charges would repel one another. In some scripts, the difference in sign was incorrectly attributed to either the proton or the α-particle having a negative charge.

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Section B

Question 9

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Question 11

(a) Many underlined the whole of one of the numbers near the centre of Fig. 11.2. Candidates would benefit from further practice at questions on analogue-to-digital conversion.

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PHYSICS

Paper 9702/43
A2 Structured Questions

Key Messages

- Candidates should be encouraged to read the command words used in each question carefully. "State and explain" indicates that an explanation is a required part of the answer. Candidates often lose credit for this type of question when they provide only a statement without an explanation.
- An important aspect of the assessment in this component is the ability to show understanding and to apply knowledge to unfamiliar situations. Candidates do, in general, require more experience of questions where these skills are being assessed.
- Candidates should explain their work fully. In particular, relevant formulae should be quoted and full substitution of values made clear. Candidates should be reminded that they may lose credit where working is not shown clearly.

General Comments

Candidates produced a wide range of responses. There were some very high-scoring papers that demonstrated a good understanding of the full range of topics.

There was no evidence that adequately prepared candidates were short of time.

The more able candidates had a thorough understanding of the syllabus content assessed in ***Section B***.

Comments on Specific Questions

Section A

Question 1

(a) In most cases a basic statement of Newton's law of gravitation was given. Relatively few answers included the condition that the law applies to point masses.

(b) The derivation of the expression often consisted of pure algebraic working without any accompanying explanatory comments. Those answers that did contain an explanation sometimes stated that the centripetal force equals the gravitational force, possibly implying that there is an equilibrium situation. It is more accurate and less ambiguous to explain that the centripetal force is provided by the gravitational force. Candidates were explicitly asked to explain their working and it was expected that the symbol used for the mass of the planet would be explained as this symbol was not given in the question.

(c) There were many good answers. The most common errors were incorrect conversions of the units of years to seconds and the units of kilometres to metres.

Question 2

(a) (i) There were many correct responses. The internal energy of a system is the sum of the kinetic and potential energies of all the molecules, due to their random motion. Candidates needed to explicitly refer to the energies "of the molecules" rather than the energies "of the system".

(ii) Many candidates appreciated that the molecules of an ideal gas have no potential energy. For the award of credit, they also needed to link this to the absence of intermolecular forces. It should be noted that the intermolecular forces of an ideal gas are zero rather than negligible.

(b) (i) The majority of answers gave the change in kinetic energy of a single molecule. The question clearly asked for the change in total kinetic energy of all the gas molecules. Candidates should be reminded to read carefully, rather than merely scan, each part of a question to ensure that key details are not overlooked.

(ii) The first law of thermodynamics needed to be stated in precise terms. It was common to see incomplete terms such as 'work done' rather than 'work done on the system' and 'change in internal energy' rather than 'increase in internal energy'. During the calculation, weaker candidates sometimes confused the heat energy supplied with the increase in internal energy.

Question 3

(a) There were many good answers. Reference must be made to "unit positive charge" in the stated definition.

(b) (i) Although many candidates correctly stated that the charges had the same sign, this was rarely supported by correct reasoning.

(ii) Comparatively few answers correctly stated that the combined electric potential is determined by adding the individual potentials due to each charge. A common misconception was that the individual potentials should be subtracted.

(iii) The vast majority of candidates thought, incorrectly, that the combined potential was a minimum at a point corresponding to the intersection of the two graph lines.

(iv) The candidates needed to understand that the combined potential would be 0.43 V. Many thought that it would be 0.29 V or 0.15 V. Those that could calculate the correct combined potential usually managed to equate the change in kinetic energy of the α-particle to its change in potential energy.

Question 4

(a) The most common correctly stated functions were for smoothing in rectifier circuits and for storing energy. It should be noted that capacitors store energy by charge separation and that this should be stated rather than "storing charge".

(b) (i) Candidates needed to explain that the potential difference across each capacitor is the same and then give the relationship between charge and capacitance.

(ii) The syllabus makes a direct reference to this derivation and so, as expected, there were many correct answers.

(c) The vast majority of circuit diagrams were correctly drawn. A small number of candidates did not read the question carefully enough and attempted to draw diagrams incorporating more than three capacitors.

Question 5

(a) (i) There were many correct answers, although some referred to the force on a charge without making it clear that it must be a moving charge.

(ii) The vast majority of answers gave the correct expression of $BA \sin \theta$, although a significant minority gave $BA \cos \theta$ which was incorrect for the angle shown in the diagram.

(b) (i) Candidates needed to explain that the vertical component of the Earth's magnetic field is always parallel to the plane of the window frame so that the flux linkage is always zero.

(ii) The calculation was usually done correctly. Sometimes a power-of-ten error was made when converting the units of the area from cm^2 to m^2.

(c) (i) An adequate statement of the law was given by most candidates.

(ii) With few exceptions, a correct calculation was performed.

(iii) Question discounted.

Question 6

(a) Only the most able candidates could explain that the path was not a circular arc in the field because the force on the particle acted vertically downwards.

(b) (i) It was generally understood that the direction of the magnetic field was into the plane of the page. For full credit it was also necessary to explain that the direction of the force due to the magnetic field was opposite to that due to the electric field. Weaker candidates frequently confused the direction of the magnetic field with the direction of the magnetic force.

(ii) Although candidates were asked explicitly to explain their working, only a small minority commented that the magnitudes of the forces due to the magnetic and electric fields were equal. However, most candidates did equate the appropriate algebraic expressions. A small minority of answers were inappropriately expressed to only one significant figure.

(c) There was widespread confusion over the effects of changing the charge, mass and speed of the particle. The key to answering this part of the question was to understand how each change affected the magnetic and electric forces acting on the particle.

Question 7

(a) (i) Most candidates knew that work function energy is the minimum energy to remove an electron from the surface. For full credit it was also necessary to explain that this minimum energy comes from a photon. A misconception among weaker candidates is that photons are emitted from the surface.

(ii) Many candidates understood that the electrons with the maximum kinetic energy are those emitted directly from the surface. However, comparatively few appreciated that there is a range of kinetic energies below this maximum value because energy is needed to bring electrons to the surface. Although the question referred to monochromatic light, there were still a significant number of candidates who commented that the photons had differing amounts of energy.

(b) (i) Two alternative methods of calculation were used to determine the work function energy of the metal surface. The most common method was to substitute a pair of values from a point on the graph line into the photoelectric equation. The other, simpler, method was to determine the threshold frequency by extrapolating the graph line and to then multiply this by the Planck constant. The value of the Planck constant could be calculated from the gradient of the graph line or simply taken from the data sheet.

(ii) The graph line was usually drawn with the same gradient, although it was sometimes incorrectly displaced to the left of the given line.

(iii) Very few candidates appreciated that the intensity determines the number of photons arriving at the surface per unit time. Intensity therefore determines the number of electrons emitted per unit time and not the energy of those electrons.

Question 8

(a) Most answers correctly defined the decay constant as the probability of decay of a nucleus per unit time. Candidates should refer to a nucleus rather than to an atom, nucleon or isotope. Similarly it is incorrect to state “per second” rather than “per unit time”. Quantities are defined in terms of other quantities and not in terms of units.

(b) (i) The calculation was usually performed successfully.

(ii) Many able candidates scored all of the available marks. The best answers explicitly explained that the krypton-92 had negligible activity after 1.0 hour. Weaker candidates often confused the initial

activity of the barium-141 with its final activity. Many candidates needed to improve the presentation of their calculation so that each step is clearly shown.

Section B

Question 9

(a) The majority of the candidates were able to give at least two properties of an ideal operational amplifier.

(b) (i) The calculation was straightforward for well-prepared candidates. The most common error was to use the expression for the gain of an inverting amplifier.

(ii) Partially incorrect graph shapes were common. The initial graph line from the origin needed to be drawn with the correct gradient until the output potential saturated at 9.0 V. It was generally understood that the sudden change in the sign of the input potential caused a sudden change in the sign of the output potential and that this transition needed to be shown by drawing a vertical line.

Question 10

(a) Many answers explained that the hydrogen nuclei possess a 'spin' and that they precess about the direction of the magnetic field. Less well understood was that the frequency of precession depends on the strength of the magnetic field and that a large magnetic field (in excess of 1 tesla) gives rise to a frequency of precession that is in the radio-frequency region of the electromagnetic spectrum.

(b) Although candidates from some Centres made a good attempt at this part of the question, many answers omitted the key points that were needed for the award of credit. The non-uniform field gives a unique value of magnetic field strength at each point in a person. Therefore the frequency of precession of hydrogen nuclei is different at different points. This enables the location of the nuclei to be determined. Furthermore, as the non-uniform field is changed it will enable the nuclei in different regions of the person to be detected.

Question 11

(a) (i) This part of the question was generally well answered.

(ii) Most candidates were able to state at least one advantage of digital transmission. A common misconception was that digital signals do not pick up noise.

(b) (i) The great majority of answers were correct. A small number of candidates incorrectly stated that block Y was either an operational amplifier or a radio-frequency amplifier.

(ii) Candidates found this question difficult. A common incomplete answer was that the "bits are received in parallel and then transmitted in series". This merely paraphrased the question. An explanation of the terms 'parallel' and 'series' was needed.

Question 12

(a) The most commonly stated correct reasons for using frequencies in the gigahertz range were that the signal would have a large bandwidth, giving rise to a large capacity for carrying information, and that the signal would not reflect from the ionosphere.

(b) Explanations needed to be precise. The reason for having two different carrier frequencies is to prevent the very low power input signal to the satellite from being swamped by the satellite's own high power transmitted signal.

(c) Many candidates had clearly practised this type of calculation. The majority could state the correct general expression relating the ratio of two powers to the number of decibels. However, a common error was to then confuse the power received at the satellite with the power transmitted from the Earth. This gave an answer of an unreasonable order of magnitude. In such instances, candidates should be encouraged to consider the validity of their answers as they may then be able to quickly identify an error in their working.

PHYSICS

Paper 9702/51

Planning, Analysis and Evaluation

Key Messages

- In **Question 1**, candidates' responses should include detailed explanations of experimental procedures.
- Graphical work should be carefully attempted and checked. Candidates should use a sharp pencil when plotting data points and use a clear 30 cm ruler when drawing the line of best fit and the worst acceptable line; care is also needed when reading information from the graph.
- The numerical answers towards the end of **Question 2** require candidates to show all their working, particularly when determining both percentage and absolute uncertainties.
- The practical skills required for this paper should be developed and practised over a period of time with a 'hands-on' approach.

General Comments

Candidates were able to access all parts of the paper and there was no evidence that the paper could not be completed in the time available.

In **Question 1**, a significant number of candidates did not realise how to change the frequency of the alternating current supplied to the coil. Candidates also found **Question 2** difficult, and weaker candidates struggled with the negative intercept in **(a)**. A common error in **(e)** was to add the percentage uncertainties.

For **Question 1**, candidates should include greater detail in their answers, and should be reminded that the boxes for the Examiner's use at the end of the question give a useful hint about the criteria used for awarding marks. In **Question 2** careless mistakes were often made in the plotting of points on the graph, drawing straight lines and not reading off information from the graph correctly. To gain maximum marks, it is essential that candidates show all of their working clearly.

It is clear that the candidates scoring the highest marks have experienced 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, Cambridge have produced two booklets – Teaching AS Physics Practical Skills and Teaching A2 Physics Practical Skills which are available from the Teacher Support Site.

Comments on Specific Questions

Question 1

Candidates were required to design a laboratory experiment to investigate how the height that a small aluminium ring rises above a coil of wire varies with the frequency of the alternating current applied to the coil and to determine a value for the constants k and n.

The initial marks were awarded for correctly identifying the independent and dependent variables. Many candidates correctly realised that the frequency of the alternating current was the independent variable and the height of the small aluminium ring was the dependent variable. Some candidates suggested varying the peak alternating current.

Marks are then available for controlling variables: candidates should show how a fair test could be carried out by keeping appropriate variables constant. It is expected that candidates will explicitly identify the variables that need to be kept constant; "controlled" is not an acceptable alternative to the word "constant".

In this case marks were available for keeping the peak alternating current constant. Credit was not given for keeping the number of turns constant in this case. Stronger candidates were able to score an additional detail mark for describing clearly a method to keep the current constant – to gain this mark candidates needed to indicate a method of changing the current (use of a rheostat) and a method of checking the magnitude of the current (use of an ammeter).

Five marks are available for the methods of data collection. Candidates were expected to draw a labelled circuit diagram for this investigation. Diagrams must be correct and clearly labelled using conventional symbols. Incorrect diagrams often had cathode-ray oscilloscopes placed in series with the coil and the power supply. Other common errors were to include a voltmeter in series with the circuit. The second mark was awarded to candidates who used a signal generator to vary the frequency. Some candidates incorrectly suggested the use of a cathode-ray oscilloscope to vary the frequency, and other candidates suggested changing the variable resistor.

To investigate the relationship, candidates needed to indicate how both the height of the ring and the frequency of the alternating current could be measured. Most candidates were able to suggest a ruler and often included it in the diagram. A large number of candidates also explained in detail how the ruler was to be checked to ensure that it was vertical. Similarly many candidates suggested the use of a cathode-ray oscilloscope to measure the frequency of the alternating current.

Within the methods of data collection, candidates should also include additional detail. When using the oscilloscope marks were available for describing how the period, and hence the frequency, could be determined from the cathode-ray oscilloscope. Some candidates incorrectly suggested the use of a video camera to record the oscillations of a needle on the ammeter to determine frequency; other candidates suggested timing the ring as it moved to its maximum height.

The diagram on the question paper showed that the ring was not totally horizontal; the final mark in this section was awarded for either measuring the height from opposite sides of the ring or waiting for the ring to stabilise. Candidates who have seen a similar experiment will realise that the ring does wobble.

There are two marks available for the analysis of the data. It was expected that candidates would state the quantities that should be plotted on each axis of a graph for the first mark. Most candidates realised that a lg h against lg f graph should be plotted, and a ln h against ln f graph was also credited. The second mark was awarded for explaining how the y-intercept of the graph could be used to determine a value for k. To gain credit candidates needed to make k the subject of the expression. There were also two additional marks available for correctly giving a logarithmic equation for the expression and for stating that the relationship would be valid if the data points on the graph are linear; some candidates did not state that the line had to be straight. Often candidates stated that the straight line would pass through the origin – this was not penalised but candidates should be encouraged to think that this would only apply if the value of k was 1.

There was one mark available for describing an appropriate safety precaution. Candidates should be encouraged to give clearly reasoned safety precautions that are relevant to the experiment; candidates were expected to describe a safety precaution relating to the hot coil. Some candidates were worried about the ring “flying off” the retort stand.

There are four marks available for additional detail. Candidates should be encouraged to write their plans including appropriate detail; often candidates’ answers suggested they lacked sufficient practical experience. Vague responses did not score.

It must be emphasised that those candidates who have followed a ‘hands on’ practical course during their studies are much better placed to score these additional detail marks. It is essential that candidates’ answers give detail relevant to the experiment in question rather than general ‘textbook’ rules for working in a laboratory.

Question 2

In this data analysis question, candidates were given data on how the resonant frequency f of an air column is affected by length d of the air column.

(a) Initially candidates were asked to determine expressions for the gradient and y-intercept if a graph of d against $1/f$ was plotted. A number of candidates did not realise that the y-intercept was negative.

(b) Most candidates correctly included the column heading, although some candidates did not include a distinguishing mark between the quantity and unit. A number of candidates lost credit for rounding errors. It is expected that the number of significant figures in calculated quantities should be the same as, or one more than, the number of significant figures in the raw data; in this case *f* was given to three significant figures so it was expected that 1/*f* would be given to three or four significant figures.

(c) (i) Candidates should be advised to ensure that the size of the plotted points is small; large "blobs" did not gain credit. Candidates should be encouraged to check plots that do not appear to follow the line of best fit. A number of candidates did not construct the error bars accurately.

(ii) Some candidates were careless in their drawing of the lines; candidates should be encouraged to use a clear 30 cm ruler. Candidates should also be encouraged to ensure that there is a balance of points on each side of the line. The worst acceptable straight line should be either the steepest possible line or the shallowest possible line that passes through all 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. A number of candidates did not score marks for their lines since they were not straight.

(iii) This part was generally answered well; most candidates clearly demonstrated the points they had used to determine the gradient. Some candidates did not use a sensibly-sized triangle for their gradient calculation. A large number of stronger candidates clearly indicated the points that they used from the line of best fit. Some candidates used their points from the table but did not gain credit because they did not lie on the line of best fit. A large number of candidates did not realise that the *x*-axis had a power of ten i.e. $(1/f) / 10^{-3}$ s.

To determine the uncertainty 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. Again stronger candidates clearly indicated the points that they used from the worst acceptable line. Some candidates were confused by which line was the best and which was the worst.

(iv) Many candidates did not realise that there was a false origin. Strong candidates substituted a value from their line into $y = mx + c$. To determine the uncertainty in the *y*-intercept, candidates need to determine the *y*-intercept from the worst acceptable line – again a point from the worst acceptable line and the gradient of the worst acceptable line needed to be substituted into $y = mx + c$. Often weaker candidates attempted a fractional method or just stated an arbitrary value.

(d) Candidates needed to determine values for *k* and *v* using their gradient and *y*-intercept values. A large number of candidates either omitted the unit or gave wrong units. Candidates were also required to give the absolute uncertainties in the values for *k* and *v*; a common error was to give the absolute uncertainty in *v* as the same as the absolute uncertainty in the gradient.

(e) (i) Candidates' values of *f* needed to be given in a specific range and their answer had to be to an appropriate number of significant figures. Many candidates did not score this mark since they had not read off correctly from the *x*-axis on the graph, which meant that the value of *f* was incorrect by a factor of 1000.

(ii) For this part it is essential that candidates show their working. A large number of candidates just added the percentage uncertainties in *v*, *d* and *k*. To determine the uncertainty in $(d + k)$, candidates needed to add the absolute uncertainties in *d* and *k*. Some candidates attempted to work out the maximum or minimum value but did not use the correct combination of maximum and minimum values. Appropriate methods are shown in the published mark scheme.

PHYSICS

Paper 9702/52

Planning, Analysis and Evaluation

Key Messages

- In **Question 1**, candidates' responses should include detailed explanations of experimental procedures.
- Graphical work should be carefully attempted and checked. Candidates should use a sharp pencil when plotting data points and use a clear 30 cm ruler when drawing the line of best fit and the worst acceptable line; care is also needed when reading information from the graph.
- The numerical answers towards the end of **Question 2** require candidates to show all their working, particularly when determining both percentage and absolute uncertainties.
- The practical skills required for this paper should be developed and practised over a period of time with a 'hands-on' approach.

General Comments

Candidates were able to access all parts of the paper and there was no evidence that the paper could not be completed in the time available.

In **Question 1**, a significant number of candidates did not realise how to change the frequency of the alternating current supplied to the coil. Candidates also found **Question 2** difficult, and weaker candidates struggled with the negative intercept in **(a)**. A common error in **(e)** was to add the percentage uncertainties.

For **Question 1**, candidates should include greater detail in their answers, and should be reminded that the boxes for the Examiner's use at the end of the question give a useful hint about the criteria used for awarding marks. In **Question 2** careless mistakes were often made in the plotting of points on the graph, drawing straight lines and not reading off information from the graph correctly. To gain maximum marks, it is essential that candidates show all of their working clearly.

It is clear that the candidates scoring the highest marks have experienced 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, Cambridge have produced two booklets – Teaching AS Physics Practical Skills and Teaching A2 Physics Practical Skills which are available from the Teacher Support Site.

Comments on Specific Questions

Question 1

Candidates were required to design a laboratory experiment to investigate how the height that a small aluminium ring rises above a coil of wire varies with the frequency of the alternating current applied to the coil and to determine a value for the constants k and n.

The initial marks were awarded for correctly identifying the independent and dependent variables. Many candidates correctly realised that the frequency of the alternating current was the independent variable and the height of the small aluminium ring was the dependent variable. Some candidates suggested varying the peak alternating current.

Marks are then available for controlling variables: candidates should show how a fair test could be carried out by keeping appropriate variables constant. It is expected that candidates will explicitly identify the variables that need to be kept constant; "controlled" is not an acceptable alternative to the word "constant".

In this case marks were available for keeping the peak alternating current constant. Credit was not given for keeping the number of turns constant in this case. Stronger candidates were able to score an additional detail mark for describing clearly a method to keep the current constant – to gain this mark candidates needed to indicate a method of changing the current (use of a rheostat) and a method of checking the magnitude of the current (use of an ammeter).

Five marks are available for the methods of data collection. Candidates were expected to draw a labelled circuit diagram for this investigation. Diagrams must be correct and clearly labelled using conventional symbols. Incorrect diagrams often had cathode-ray oscilloscopes placed in series with the coil and the power supply. Other common errors were to include a voltmeter in series with the circuit. The second mark was awarded to candidates who used a signal generator to vary the frequency. Some candidates incorrectly suggested the use of a cathode-ray oscilloscope to vary the frequency, and other candidates suggested changing the variable resistor.

To investigate the relationship, candidates needed to indicate how both the height of the ring and the frequency of the alternating current could be measured. Most candidates were able to suggest a ruler and often included it in the diagram. A large number of candidates also explained in detail how the ruler was to be checked to ensure that it was vertical. Similarly many candidates suggested the use of a cathode-ray oscilloscope to measure the frequency of the alternating current.

Within the methods of data collection, candidates should also include additional detail. When using the oscilloscope marks were available for describing how the period, and hence the frequency, could be determined from the cathode-ray oscilloscope. Some candidates incorrectly suggested the use of a video camera to record the oscillations of a needle on the ammeter to determine frequency; other candidates suggested timing the ring as it moved to its maximum height.

The diagram on the question paper showed that the ring was not totally horizontal; the final mark in this section was awarded for either measuring the height from opposite sides of the ring or waiting for the ring to stabilise. Candidates who have seen a similar experiment will realise that the ring does wobble.

There are two marks available for the analysis of the data. It was expected that candidates would state the quantities that should be plotted on each axis of a graph for the first mark. Most candidates realised that a lg h against lg f graph should be plotted, and a ln h against ln f graph was also credited. The second mark was awarded for explaining how the y-intercept of the graph could be used to determine a value for k. To gain credit candidates needed to make k the subject of the expression. There were also two additional marks available for correctly giving a logarithmic equation for the expression and for stating that the relationship would be valid if the data points on the graph are linear; some candidates did not state that the line had to be straight. Often candidates stated that the straight line would pass through the origin – this was not penalised but candidates should be encouraged to think that this would only apply if the value of k was 1.

There was one mark available for describing an appropriate safety precaution. Candidates should be encouraged to give clearly reasoned safety precautions that are relevant to the experiment; candidates were expected to describe a safety precaution relating to the hot coil. Some candidates were worried about the ring “flying off” the retort stand.

There are four marks available for additional detail. Candidates should be encouraged to write their plans including appropriate detail; often candidates’ answers suggested they lacked sufficient practical experience. Vague responses did not score.

It must be emphasised that those candidates who have followed a ‘hands on’ practical course during their studies are much better placed to score these additional detail marks. It is essential that candidates’ answers give detail relevant to the experiment in question rather than general ‘textbook’ rules for working in a laboratory.

Question 2

In this data analysis question, candidates were given data on how the resonant frequency f of an air column is affected by length d of the air column.

(a) Initially candidates were asked to determine expressions for the gradient and y-intercept if a graph of d against $1/f$ was plotted. A number of candidates did not realise that the y-intercept was negative.

(b) Most candidates correctly included the column heading, although some candidates did not include a distinguishing mark between the quantity and unit. A number of candidates lost credit for rounding errors. It is expected that the number of significant figures in calculated quantities should be the same as, or one more than, the number of significant figures in the raw data; in this case *f* was given to three significant figures so it was expected that 1/*f* would be given to three or four significant figures.

(c) (i) Candidates should be advised to ensure that the size of the plotted points is small; large "blobs" did not gain credit. Candidates should be encouraged to check plots that do not appear to follow the line of best fit. A number of candidates did not construct the error bars accurately.

(ii) Some candidates were careless in their drawing of the lines; candidates should be encouraged to use a clear 30 cm ruler. Candidates should also be encouraged to ensure that there is a balance of points on each side of the line. The worst acceptable straight line should be either the steepest possible line or the shallowest possible line that passes through all 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. A number of candidates did not score marks for their lines since they were not straight.

(iii) This part was generally answered well; most candidates clearly demonstrated the points they had used to determine the gradient. Some candidates did not use a sensibly-sized triangle for their gradient calculation. A large number of stronger candidates clearly indicated the points that they used from the line of best fit. Some candidates used their points from the table but did not gain credit because they did not lie on the line of best fit. A large number of candidates did not realise that the *x*-axis had a power of ten i.e. $(1/f) / 10^{-3}$ s.

To determine the uncertainty 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. Again stronger candidates clearly indicated the points that they used from the worst acceptable line. Some candidates were confused by which line was the best and which was the worst.

(iv) Many candidates did not realise that there was a false origin. Strong candidates substituted a value from their line into $y = mx + c$. To determine the uncertainty in the *y*-intercept, candidates need to determine the *y*-intercept from the worst acceptable line – again a point from the worst acceptable line and the gradient of the worst acceptable line needed to be substituted into $y = mx + c$. Often weaker candidates attempted a fractional method or just stated an arbitrary value.

(d) Candidates needed to determine values for *k* and *v* using their gradient and *y*-intercept values. A large number of candidates either omitted the unit or gave wrong units. Candidates were also required to give the absolute uncertainties in the values for *k* and *v*; a common error was to give the absolute uncertainty in *v* as the same as the absolute uncertainty in the gradient.

(e) (i) Candidates' values of *f* needed to be given in a specific range and their answer had to be to an appropriate number of significant figures. Many candidates did not score this mark since they had not read off correctly from the *x*-axis on the graph, which meant that the value of *f* was incorrect by a factor of 1000.

(ii) For this part it is essential that candidates show their working. A large number of candidates just added the percentage uncertainties in *v*, *d* and *k*. To determine the uncertainty in $(d + k)$, candidates needed to add the absolute uncertainties in *d* and *k*. Some candidates attempted to work out the maximum or minimum value but did not use the correct combination of maximum and minimum values. Appropriate methods are shown in the published mark scheme.

PHYSICS

Paper 9702/53

Planning, Analysis and Evaluation

Key Messages

- In **Question 1**, candidates' responses should include detailed explanations of experimental procedures.
- Graphical work should be carefully attempted and checked. Candidates should use a sharp pencil when plotting data points and use a clear 30 cm ruler when drawing the line of best fit and the worst acceptable line; care is also needed when reading information from the graph.
- The numerical answers towards the end of **Question 2** require candidates to show all their working, particularly when determining both percentage and absolute uncertainties.
- The practical skills required for this paper should be developed and practised over a period of time with a 'hands-on' approach.

General Comments

Candidates were able to access all parts of the paper and there was no evidence that the paper could not be completed in the time available.

For **Question 1**, candidates should include greater detail in their answers, and should be reminded that the boxes for the Examiner's use at the end of the question give a useful hint to candidates about the criteria used for awarding marks. In **Question 2** careless mistakes were often made in the plotting of points on the graph, drawing straight lines and not reading off information from the graph correctly. To gain maximum marks, it is essential that candidates show all of their working clearly. Some candidates were sometimes confused between absolute or percentage uncertainties.

It is clear that the candidates scoring the highest marks have experienced 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, Cambridge have produced two booklets – Teaching AS Physics Practical Skills and Teaching A2 Physics Practical Skills which are available from the Teacher Support Site.

Comments on Specific Questions

Question 1

Candidates were required to design a laboratory experiment to investigate how the resistance R of nichrome varies with temperature θ.

The initial marks were awarded for correctly identifying the independent and dependent variables. Most candidates correctly realised that the temperature was the independent variable and the resistance was the dependent variable.

Marks are then available for controlling variables: candidates should indicate how a fair test could be made by keeping appropriate variables constant. It is expected that candidates will explicitly identify the variables that need to be kept constant; "controlled" is not an acceptable alternative to the word "constant". In this case a mark was given for keeping the length of the nichrome constant.

Five marks are available for the methods of data collection. Candidates were expected to draw a labelled diagram for this investigation. It was expected that the nichrome would be clearly labelled in a water bath or oven. A second mark was available for an appropriate circuit diagram to determine the resistance of the

nichrome wire. Diagrams must be correct using clearly labelled using conventional symbols. Some diagrams were drawn badly; other common errors were to include a voltmeter in series with the circuit or power supplies connected in series with ohmmeters.

To investigate the relationship, candidates needed to indicate how both the temperature and the resistance of the nichrome wire could be measured. Most candidates were able to suggest a thermometer and often included it in the diagram. A large number of candidates explained how the resistance was determined from their circuit.

The final mark in this section was awarded for a method to determine the resistance of nichrome at 0 °C. Some candidates did not realise that it was necessary to have an ice-water mixture or did not describe the procedure in sufficient detail for credit.

There are two marks available for the analysis of the data. It was expected that candidates would state the quantities that should be plotted on each axis of a graph for the first mark. In this case log-log graphs could not be credited. The common graphs suggested were either R against θ or R/R_0 against θ. The second mark was awarded for explaining how α could be determined. It was expected that α would be made the subject of the relationship. There were also two additional marks available for correctly stating that the relationship would be valid if the data points on the graph are linear; some candidates did not state that the line had to be straight. Often candidates incorrectly stated that the straight line would pass through the origin. Candidates should be encouraged to think what the y-intercept represents.

There was one mark available for describing an appropriate safety precaution. Candidates should be encouraged to give clearly reasoned safety precautions that are relevant to the experiment; candidates were expected to describe a safety precaution relating to the hot wire or hot water or hot container.

There are four marks available for additional detail. Candidates should be encouraged to write their plans including appropriate detail; often candidates' answers suggested they lacked sufficient practical experience. Vague responses did not score.

It must be emphasised that those candidates who have followed a 'hands on' practical course during their studies are much better placed to score these additional detail marks. It is essential that candidates' answers give detail relevant to the experiment in question rather than general 'textbook' rules for working in a laboratory.

Question 2

In this data analysis question, candidates were given data on how the stopping distance d of a motorcycle varies with speed v.

(a) Initially candidates were asked to determine expressions for the gradient and y-intercept if a graph of d/v against v was plotted. This was generally answered well.

(b) Most candidates correctly included the column heading, although some candidates did not include a distinguishing mark between the quantity and unit. A number of candidates lost credit for rounding errors. It is expected that the number of significant figures in calculated quantities should be the same as, or one more than, the number of significant figures in the raw data; in this case v was given to two significant figures so it was expected that d/v would be given to two or three significant figures. Some candidates did not work out the absolute uncertainties in d/v correctly – the maximum value of d/v is given by the maximum d value divided by the minimum v value, etc.

(c) (i) Candidates should be advised to ensure that the size of the plotted points is small; large "blobs" did not gain credit. Candidates should be encouraged to check plots that do not appear to follow the line of best fit. A number of candidates did not construct the error bars accurately.

(ii) Some candidates were careless in their drawing of the lines; candidates should be encouraged to use a clear 30 cm ruler. Candidates should also be encouraged to ensure that there is a balance of points on each side of the line. The worst acceptable straight line should be either the steepest possible line or the shallowest possible line that passes through all 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. A number of candidates did not score marks for their lines since they were not straight.

(iii) This part was generally answered well; most candidates clearly demonstrated the points they had used to determine the gradient. Some candidates did not use a sensibly-sized triangle for their gradient calculation. A large number of stronger candidates clearly indicated the points that they used from the line of best fit. Some candidates used their points from the table but did not gain credit because they did not lie on the line of best fit.

To determine the uncertainty 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. Again stronger candidates clearly indicated the points that they used from the worst acceptable line. Some candidates were confused by which line was the best and which was the worst.

(iv) Many candidates did not realise that there was a false origin. Strong candidates substituted a value from their line into $y = mx + c$. To determine the uncertainty in the y-intercept, candidates need to determine the y-intercept from the worst acceptable line – again a point from the worst acceptable line and the gradient of the worst acceptable line needed to be substituted into $y = mx + c$. Often weaker candidates attempted a fractional method or just stated an arbitrary value.

(d) (i) Candidates needed to determine values for a and t using their gradient and y-intercept values. A large number of candidates either omitted the unit or gave wrong units.

(ii) For this part it is essential that candidates show their working. Generally this part was answered well, although some candidates were confused when calculating the percentage uncertainty in a. Appropriate methods are shown in the published mark scheme.