PHYSICS

Paper 9702/11
Multiple Choice

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

General Comments

This paper demands quick and accurate working by candidates, but the time of 90 seconds per answer is made possible by having many questions that can be answered after a quick read through the question. Candidates should be advised never to spend a disproportionately long time on any one question. Candidates must be encouraged to work through many questions. There is plenty of space on the paper for writing. Care with units is essential. Prefix errors are a cause of many wrong answers as are corresponding power of 10 errors. Candidates must be certain to look critically at any answer they give to see if it makes basic sense.

Comments on Specific Questions

Question 7

Answer **C** was slightly more popular than the correct answer **B**. There is no way in which the body can have a constant acceleration. It is the acceleration that decreases as the body falls.

Question 8

Many candidates gave the time at which the two trains are travelling at the same velocity, but the express train is not overtaking the goods train until it is travelling at twice this velocity, as is shown clearly on a velocity-time sketch graph. This is the sort of question where a graph should be quickly sketched by a candidate on the question paper. It is important to write out the working and not to try to answer this type of question by thinking only.

Question 14

This question was found to be problematic. A significant number of candidates chose **C**, implying that you needed a greater force as the distance x is increased. About half of the candidates chose **A**: although if you double x you will only need half the value of F, if you double it again you cannot possibly need zero force. The graph cannot be a straight line.

Question 16

There is plenty of space on the paper for a triangle of forces to be drawn, and if the angles are reasonably accurate it will be seen that the order is W, H, T. (A less accurately drawn diagram might get H, W, T, but that is not an option.)

Question 17

This was tricky. It is necessary to deal with the bottom of the ball at 72 cm at the start and 37 cm at the end. This gives (37/72) × 0.75 J = 0.3854 J.

Question 18

Candidates work out the mass of air passing the blades in one second and use its speed in this calculation. Many then do not realise that the speed must be used again in $\frac{1}{2}mv^2$.

Question 19

The force exerted by the wheel on the rope is 80 N. The distance moved against this force in one second is 50 × 0.30 = 15 m. The power provided by the motor is therefore 80 N × 15 m s^{-1} = 1200 W = 1.2 kW.

Question 24

Many candidates forget to include the intensity of the light wave. Twice the amplitude implies four times the intensity, and then focussing increases the power per unit area by a further factor of 3.

Question 28

Answer **B** was more popular than the correct answer **C**, but **B** cannot in any way keep the same wave pattern.

Question 33

Many candidates thought that the terminal p.d. would be unchanged. An increase in internal resistance will decrease the terminal p.d. and also decrease the output power.

Question 35

This question was difficult and the statistics suggested that many candidates tried to guess the correct answer. Obtaining the correct answer requires careful determination of the resistance on each 'half' of the circuit.

Question 36

Many candidates thought that the voltmeter would read zero. The resistance of the ammeter and resistor in parallel is close to 0.1 Ω, so the potential difference of 2 V must be mostly across the much larger resistance of the voltmeter.

Question 37

This was another electricity question that candidates found difficult. If the variable resistance is zero the current will be large and the voltmeter reading will be zero. When the variable resistance is 10 Ω the current will be reduced, but not zero, and the voltmeter reading will be high.

PHYSICS

Paper 9702/12
Multiple Choice

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

General Comments

This paper demands quick and accurate working by candidates, but the time of 90 seconds per answer is made possible by having many questions that can be answered after a quick read through the question. Candidates should be advised never to spend a disproportionately long time on any one question. Candidates must be encouraged to work through many questions. There is plenty of space on the paper for writing. Care with units is essential. Prefix errors are a cause of many wrong answers as are corresponding power of 10 errors. Candidates must be certain to look critically at any answer they give to see if it makes basic sense.

Comments on Specific Questions

Question 1

A significant number of candidates could not pick out **B** as containing the required one vector and one scalar quantity. This was a straightforward recall question.

Question 3

Many candidates chose **C** here, where the resultant is clearly at 45° to the horizontal instead of the direction shown in the correct answer, **A**.

Question 9

Candidates found this question difficult. There is a pitfall here that many of the able candidates fell into. In calculating the mass *m* of air that hits the wall in one second, the speed of the air must be involved: $m = 12\,\text{m}^2 \times 33\,\text{m} \times 1.2\,\text{kg}\,\text{m}^{-3}$. The rate of change of momentum is therefore this expression multiplied by its velocity, $33\,\text{m}\,\text{s}^{-1}$, giving an answer of 16 000 N. Keeping units in a calculation like this will result in an answer with the units of momentum. Missing out the 33 m will give incorrect units for force.

Question 13

About a third of candidates chose the correct answer for this question. The key to the answer is in the word '**must**'. At first sight both **B** and **C** seem possible, but **C** is not correct if the mass of the body is changing, whereas **B** is always correct under any circumstances.

Question 14

Many candidates did not include the weight of the beam here.

Question 19

Temperature depends only on the average speed of molecules. Molecules in ice at 0 °C and molecules in water at 0 °C have the same average speed and therefore the same average kinetic energy.

Question 20

The answer to this question cannot reliably be obtained by guesswork. Eliminating the pressure at P gives $(h_1 - h_2)\rho g = 8000$ Pa, so $(h_1 - h_2) = 0.060$ m. **D** is the only answer that fits.

Question 23

The model has a load that is 1/1000 of the full-size load and its cable will have an area of cross-section that is 1/100 that of the crane's. This gives the ratio of the stresses to be 10.

Question 24

Taking the wavelength of violet light to be 4×10^{-7} m gives the frequency to be 7.5×10^{14} Hz or 10^{15} when rounded to the nearest power of 10.

Question 32

Many candidates correctly found the resistance of one strand of wire, but forgot to divide by 12, the number of strands. This gave **D** as a very popular incorrect answer.

Question 39

Roughly the alpha particle has a mass of 4 u, so $4 \times 1.66 \times 10^{-27}$ kg. This gives 6.6×10^{-27} kg or 10^{-26} when rounded up. A number of candidates chose **A**, and these candidates may have incorrectly rounded.

PHYSICS

Paper 9702/13
Multiple Choice

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

General Comments

This paper demands quick and accurate working by candidates, but the time of 90 seconds per answer is made possible by having many questions that can be answered after a quick read through the question. Candidates should be advised never to spend a disproportionately long time on any one question. Candidates must be encouraged to work through many questions. There is plenty of space on the paper for writing. Care with units is essential. Prefix errors are a cause of many wrong answers as are corresponding power of 10 errors. Candidates must be certain to look critically at any answer they give to see if it makes basic sense.

Comments on Specific Questions

Question 8

For an object starting from rest, $s = ½at^2$ so $s/t^2 = ½a$. On the graph s/t^2 is the gradient so, to find the acceleration, twice the gradient is needed. Some candidates incorrectly chose **A** but a significant number chose **B**, forgetting about the ½ term completely.

Question 9

The unbalanced force, 392 N, has to accelerate all the mass, 1240 kg, and not just the mass of the lift and passenger.

Question 14

Answers **A** and **D** were almost equally popular. The correct answer is **A**, because the total work done depends only on the difference in height (which is zero).

Question 19

The full-size load has 1000 times the weight of the model; the area of cross-section of the cable itself is 100 times that of the model; the length of the cable is 10 times that of the model. The ratio of the two extensions using force × length / (Y × area) = 1000 × 10 / (1 × 100) = 100, answer **C**.

Question 21

The problem here was the units, as so often happens when making measurements. Using cm and mJ meant factors of 100 and 1000 had to be dealt with.

Question 27

There are three maxima on each side and one undeflected, giving 7 in total. Many candidates simply gave 3.

Question 32

This question needs careful thinking. The diameter of the wire is falling linearly so the area of cross-section is not falling linearly. There is a greater percentage fall per unit length at the narrow end than at the wide end. This means that the potential difference per unit length is less at the wide end than at the narrow end. This makes the correct answer **C**. More candidates thought that **B** was the correct answer, but **B** describes a wire of uniform cross-section.

Question 36

When the variable resistor has value zero, there is 12 V across the 2 Ω resistor and the current is a maximum. When the variable resistor is at 10 Ω, the current is a minimum and the voltmeter will read 2 V. This gives **B** as the answer.

PHYSICS

Paper 9702/21
AS Structured Questions

Key Messages

- Candidates should be encouraged to treat the number of marks for each part of a question as a guide to the amount of detail required.

- 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.

- In answering "show that" questions, candidates should show all the steps in their working. If the final answer is numerical, it should be calculated and not simply assumed to be the given value.

- 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

Many candidates lost credit because they were not able to recall standard definitions or principles. The statements given were not satisfactory at AS Level for many of the questions. Candidates should be encouraged to learn definitions thoroughly.

It should be remembered that a proportion of the marks are dedicated to application and extension of the basic content of the syllabus. In order to score highly, candidates do need to have a thorough understanding of the subject matter.

Comments on Specific Questions

Question 1

(a) A common answer was based on extension being proportional to force. Reference should have been made to the wire returning to its original length on removal of the load. Candidates often used imprecise or unsuitable terms such as "size", "shape", "position" and "state".

(b) The final expression for the SI units of energy per unit volume was given. Many candidates did derive the units of energy. Others lost credit by just giving an expression for the units of energy, without any explanation. In "show that" questions candidates should be advised that full details of the procedure are vital.

(c) This proof required that candidates should derive the units for the Young modulus and also state that strain has no unit. A common error was to quite correctly state that strain is the ratio of extension and original length but then to go on to give the unit of strain as '0' or '1'.

Question 2

(a) Candidates should be advised to learn the meanings of such terms. Many merely mentioned scalar and vector quantities. Others referred to "gravity" rather than gravitational force.

(b) (i) This was generally answered correctly. A minority did not show the 69 N force acting along the rope. Rather, they showed vertical and horizontal components, many without explanation, and consequently did not answer the question.

(ii) The majority of answers were correct, although some confused sine with cosine. Candidates should be advised to use the data provided on page 2 of the question paper. The use of the approximation $g = 10\,\mathrm{m\,s^{-2}}$ should be avoided unless the question states specifically that this value is to be used.

(iii) This was generally answered well. Most used $69\cos\theta$, but a minority correctly used Pythagoras' theorem.

Question 3

(a) There were very few complete answers. Many candidates merely stated that, as the object falls, potential energy is converted into kinetic energy. At this level, it was expected that reduction in gravitational potential energy would be related to decrease in height, kinetic energy would be related to increase in speed and increase in thermal energy would be related to work done against air resistance.

(b) (i) There were many correct answers. The usual errors were either associated with powers of ten or a failure to square the speed.

(ii) 1. A significant number of candidates gave the change in energy as being equal to the change in potential energy.

(ii) 2. A majority of answers were based on the energy loss being equated to the product of the frictional force and the distance moved. A significant number of candidates gave their answer as the weight of the object.

Question 4

(a) When defining pressure, a statement of the ratio is essential. The use of the unclear term "force over area" should be discouraged.

(b) Many answers lost credit by being too simplistic, being based on a statement that the molecules collide with the walls, producing a force/pressure. It was expected that reference would be made to the random nature of the motion of the gas molecules – not a random motion of the gas. Any discussion of force/impulse should have been preceded by a reference to momentum change. Finally, the averaging of the force/impulse from many collisions to give pressure should have been included.

(c) Most answers were confined to a statement as to what is meant by elastic collisions. Some described elastic collisions as where there is energy conservation instead of kinetic energy conservation. Very few realised that the consequence of elastic collisions is that the temperature of the gas does not change.

Question 5

(a) The necessary conditions (i.e. coherence, superposition and phase/path difference) for maxima were stated in many answers, but frequently there was a lack of clarity. When referring to phase, it was not made clear whether the sources or the waves were being considered. Some candidates did, quite correctly, consider polarisation.

(b) This was a simple derivation. A small minority of answers involved the speed of sound. Others gave an incorrect power of ten for GHz.

(c) There were very few comprehensive answers where the number of maxima or minima between O and P were considered. The most common answer was to assume a minimum half-way between O and P and then to have the first maximum at P.

(d) Many answers did include narrower slits placed closer together. It was common to find that the question had not been read carefully and, consequently, changes other than those to the slits were suggested. Candidates do need to be encouraged to be precise. Vague answers such as "make the slits smaller" do not make it clear as to what aspect of the slits is being considered.

Question 6

(a) Generally, correct answers were given. Some candidates did not read the question carefully and, as a result, did not consider these specific examples but instead referred to "other forms of energy".

(b) Weaker candidates found difficulty with this question. There was confusion between power and energy. Frequently, general expressions were quoted that did not include the terms E, R_1 and R_2.

(c) Candidates should be encouraged to quote relevant formulae at the start of any determination. Many answers involved a jumble of numbers and letters without any explanation. A significant number of candidates gave their answer as the ratio of the resistances without any consideration of the same current in the resistors.

(d) There were some answers that were explained adequately but it was common to find that it was not appreciated that the p.d. across the resistors would be the same, with different currents.

Question 7

(a) Many answers involved α-particles having no deviation, rather than small deviations. It is important that candidates realise that the great majority were subject to small deviations of less than 10° and that very few had deviations greater than 90°. A reference to the relative numbers and to the sizes of the angles was expected.

(b) A common statement was that the nucleus has a large mass. This is insufficient. It should be stated that the mass of the atom is concentrated in the charged nucleus. Likewise, stating that the nucleus is small has little meaning until a comparison is made with the size of the atom. Few candidates linked the observations in **(a)** with the conclusions in **(b)**.

PHYSICS

Paper 9702/22
AS Structured Questions

Key Messages

- Candidates should be encouraged to treat the number of marks for each part of a question as a guide to the amount of detail required.
- 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.
- In answering "show that" questions, candidates should show all the steps in their working. If the final answer is numerical, it should be calculated and not simply assumed to be the given value.
- 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

The working for calculations was generally well presented and given in the detail required, but there were many instances where the detail required for explanations was provided in general terms and not related to the question.

Many candidates lost credit because they were not able to recall standard definitions or principles. The statements given were not satisfactory at AS Level for many of the questions. Candidates should be encouraged to learn definitions thoroughly.

Comments on Specific Questions

Question 1

The knowledge of SI base units was generally good. The answers for energy transformations were often not given in the detail required.

(a) The majority of candidates correctly determined the base units of power. A variety of different equations were used as the starting point in this determination. There were some errors in cancelling powers e.g. s^{-2}/s was given as s^{-1}. A few candidates did not give base units but left their answer in terms of N, W or $J\,s^{-1}$.

(b)(i) The majority of candidates gave an equation with clear substitution of the base units for the quantities involved. The units for v^3 were not always derived or shown correctly. The cancelling of the units was sometimes poor and difficult to follow. The last mark was often not awarded as the candidates suggested that *C* was zero or one. Candidates should be advised that in "show that" questions the presentation of the all the working must be given and be clear.

(ii) The majority of candidates made correct substitutions into the given equation. A significant number of candidates were unable to calculate the electric power input from the given output power and efficiency of 55%. Some completely ignored the efficiency while others calculated less power input than the given output. There were some errors made in calculating the cube root. There were a significant number of candidates who scored full marks for this part.

(iii) Candidates found it difficult to answer this question with the amount of detail required at this level. Many answers did not give sufficient detail of the power losses or where in the turbine the power losses occurred. The first marking point on the mark scheme was seldom given.

Question 2

The knowledge and understanding of the links between force, mass, acceleration and momentum were shown to be understood by a significant number of candidates. The need to improve various concepts in this area was shown by many candidates.

(a) The majority of candidates gave the answer required at this level. There were a significant number who gave $F = ma$. This answer is not acceptable and the learning outcome in the syllabus specifies the form required.

(b) (i) A significant number of candidates gave correctly a constant acceleration for the first two seconds and then an acceleration that instantaneously decreased to zero. The acceleration was not shown to be zero for the last two seconds even by many of the stronger candidates. The value of the force at time $t = 0$ was misread by a number of candidates and therefore the acceleration was calculated incorrectly. Some candidates drew a straight line (from $a = 0$, $t = 0$) showing a constant increase in the acceleration with a constant force.

(ii) The graph for the first two seconds was again given correctly by the stronger candidates. Careless mis-plotting of the momentum value at two seconds was evident in some scripts, and candidates lost credit for this. The misconception that the momentum would go to zero as the force was zero was given by a significant number of candidates. Weaker candidates showed that this is an area in which they needed further guidance.

Question 3

This question was found to be demanding by the majority of candidates.

(a) The correct definition was given by a significant number of well-prepared candidates. Candidates often gave inaccurate definitions that referred to a force rather than to the weight or to a point where weight acts rather than where it seems to act.

(b) (i) This was generally well answered. Candidates should be advised to complete calculations as some included the trigonometric function in the answer and were not awarded the mark.

(ii) Many candidates did not give an acceptable statement. Key details were omitted or the definition of the moment of a force was given.

(iii) The candidates who were able to give a correct statement in **(ii)** completed the calculation with little difficulty. Candidates should be advised that in "show that" questions the answer from their working should be worked out rather than just quoting the given value. The performance of candidates could be improved with practice taking moments about various points on a body to show how the principle can be applied.

(iv) This question was generally well answered.

(c) The majority of candidates gave the requirement for equilibrium in terms of the resultant force being zero. Only a small minority went on to explain how the known forces did not add up to zero and that an additional force was required at A to produce equilibrium. In such questions candidates should be advised to compare the upward forces with the downward forces to show that the resultant is not zero.

Question 4

Candidates found this question difficult.

(a) The majority of diagrams did not include a source of light or smoke or a closed cell. Only a small minority drew carefully labelled diagrams. A significant number described an experiment on diffusion of gases.

(b) Very few candidates described the observations of random movement of specks of light. The majority referred to the smoke particles and gave conclusions rather than observations.

(c) The majority of candidates did not give the detail asked for in the question. An explanation was rarely associated with a given statement. Many gave properties of an ideal gas or statements from the kinetic theory.

Question 5

(a) (i) This was generally well answered by the vast majority of candidates.

(ii) The stronger candidates were able to describe the meeting or overlapping of an incident wave from the vibrator and a reflected wave from the wall. Greater detail was required for the second mark, such as stating that there is interference between these waves to produce standing waves. Candidates should be advised that merely stating the general description of how stationary waves are formed is not sufficient when a specific example is referred to in the question.

(b) (i) The majority of candidates knew the positions of the nodes and antinodes. Credit was sometimes lost when omissions were made e.g. at the ends P and Q of the wave or the middle antinode.

(ii) This was generally well answered. The weaker candidates were not able to link their answer to **(a)(i)** for the wavelength with the number of waves shown on Fig. 5.2.

(iii) The majority of candidates considered the wave shown on Fig. 5.2 to be a progressive wave when calculating the position of the waveform after a further 5 ms. The drawing of the stationary wave every ¼ of a period would help candidates understand the variations in the waveform.

Question 6

The majority of candidates scored at least half of the available marks on this question. Poor answers were generally seen for the definition in **(a)** and in the use of an incorrect power of ten in **(b)(iii)**.

(a) (i) Only a minority of candidates were able to give a satisfactory answer. Candidates should be informed that a symbol equation such as It will only gain marks for a definition if the symbols are defined. Many candidates confused the definition with that of current or gave a mixture of units and quantities.

(b) (i) This was generally well answered.

(ii) This was generally well answered.

(iii) The correct formula was used by the majority of candidates but arithmetic errors often resulted in an incorrect final answer.

(iv) The stronger candidates were generally able to determine the total number of electrons. Only a minority went on to determine the number of electrons per second. The weaker candidates often gave no response.

Question 7

(a) (i) This was generally well answered.

(ii) The majority of candidates were not awarded credit because their answers lacked detail or the process of a nuclear reaction was not completely understood. The question stated that there was a difference in mass. The candidate was expected to realise that there was less mass on the right hand side and that this mass was released as energy.

(b) This was generally well answered. A small minority confused spontaneous with random.

PHYSICS

Paper 9702/23
AS Structured Questions

Key Messages

- Candidates should be encouraged to treat the number of marks for each part of a question as a guide to the amount of detail required.
- 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.
- In answering "show that" questions, candidates should show all the steps in their working. If the final answer is numerical, it should be calculated and not simply assumed to be the given value.
- 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

The working for calculations was generally well presented and given in the detail required, but there were many instances where the detail required for explanations was provided in general terms and not related to the question.

Many candidates lost credit because they were not able to recall standard definitions or principles. The statements given were not satisfactory at AS Level for many of the questions. Candidates should be encouraged to learn definitions thoroughly.

Comments on Specific Questions

Question 1

The knowledge of SI base units was generally good. The sketches of relationships that were not straight line graphs seemed to cause problems for the majority of candidates.

(a) The vast majority of candidates gave the correct response to this straightforward introduction to the paper.

(b) (i) The majority of candidates were able to determine the base units of *K* by introducing the correct base unit for current. Incorrect answers were a result of introducing charge as a base unit or with candidates making arithmetic errors when rearranging the equation.

(ii) The majority of candidates were unable to represent the relationship for the variation of distance x with force *F* in graphical form. Many candidates considered the variation to be a straight line with negative gradient.

(iii) A minority of candidates gave the correct sketch. Candidates should be encouraged to improve their knowledge with practice involving relationships that do not give straight line graphs.

Question 2

There was a lack of detail and accuracy given in answers to many parts of this question.

(a) (i) The answers required a specific reference to the detail given in the question. The majority of answers were not linked to the path shown in Fig. 2.1.

(ii) The accepted definition of acceleration was given by a minority of candidates. Candidates should learn the standard definitions required for this syllabus.

(b) (i) The majority of candidates correctly calculated the distance fallen by determining the area under the line on the graph shown in Fig. 2.3. The graph axis for either the velocity or the time was misread by a significant number of candidates. A small number made the error of using the final velocity instead of the average velocity in their calculation.

(ii) There were a significant number of correct solutions for the average acceleration. Candidates would benefit from practice involving calculations were the initial and final velocities are in opposite directions. A minority of candidates did not read the question and determined the instantaneous acceleration by calculating the gradient of a line drawn as a tangent to the curve.

(c) (i) The majority of candidates did not read the question and use information from Fig. 2.3 to explain their answer. A comparison between the two straight lines on the graph before and after the rebound was seldom described by candidates.

(ii) The majority of candidates did not read the question and use information from Fig. 2.3 to explain their answer. A comparison between the two areas on the graph before and after the rebound was seldom described by candidates.

Question 3

The calculations were generally well presented. The statements given for **(a)** were often not given in the detail required.

(a) (i) The accepted statement of the principle of conservation of momentum was given by a minority of candidates. Candidates should learn the standard definitions required for this syllabus.

(ii) The majority of candidates gave unacceptable answers. The conservation of energy or momentum was given for elastic collisions. The conservation of total kinetic energy was required for elastic collisions and the loss of kinetic energy for inelastic collisions.

(b) (i) The correct solution was given by a significant number of candidates. The addition of the initial momentum of the two objects was determined without reference to the fact that they were travelling in opposite directions by some candidates.

(ii) The correct comparison of the total kinetic energy before and after the collision was made by a large number of candidates. There were some candidates who subtracted the two initial kinetic energies presumably considering the opposite directions of the two objects as a factor. A significant number of candidates gave no conclusion after making the calculations, or gave an answer having made no calculations. The number of marks available should indicate to candidates the amount of detail required.

Question 4

(a) (i) The definition was generally given correctly. The detail of the *cross-sectional* area is a requirement for the definition.

(ii) The definition was generally given correctly. The detail of the *original* length is a requirement for the definition.

(b) (i) There were many correct solutions. A significant number of candidates were unable to determine the strain from the information given. The Young modulus was also used with an incorrect power of ten.

(ii) A significant number of candidates gained full marks owing to the application of error carried forward from **(i)**. The conversion from mm^2 to m^2 for the area caused problems for some candidates.

Question 5

There appeared to be a general lack of understanding of the difference between phase difference and path difference.

(a) The required statement was given by a significant number of candidates. There were some statements that described the addition of amplitude that were not accepted and some did not describe what was added to obtain a resultant at all.

(b) (i) There was confusion between path difference and phase difference. A large number of candidates appeared not to know the phase difference required for a maximum and a minimum.

(ii) The correct value for the wavelength was determined by the vast majority of candidates.

(iii) This was a difficult final part to the question that was correctly answered by a small number of candidates. The working for the path difference and its relationship to the wavelength was required from first principles.

Question 6

The basic understanding of a potential divider circuit was understood by a significant number of candidates.

(a) A correct definition was given by minority of candidates.

(b) (i) The correct answer was given by most candidates.

(ii) A significant number of candidates obtained the correct answer.

(c) (i) The majority of candidates selected the correct value for the resistance of the LDR for maximum light intensity. The majority of these candidates made a correct calculation for the two resistors in parallel.

(ii) The reduction in the value of the total resistance of R_2 and the LDR in parallel compared with R_2 on its own was only realised by a minority of candidates. The link with a reduced proportion of the overall resistance in the circuit and hence a reduced minimum potential difference across R_2 was rarely described.

Question 7

(a) (i) Many very brief descriptions of the atom of uranium were given. Candidates should be encouraged to pay attention to the number of marks available: here the four marks available should have been an indication that the description needed detail.

(ii) The explanations given by the vast majority of candidates did not answer the question with reference to the nuclei of the isotopes of uranium. The general comparison of *nuclei* was seldom described. The comparison of atoms or elements did not gain credit.

(b) (i) The correct values were determined by only a small number of candidates. The values needed for the neutron seemed to cause problems for many of the candidates.

(ii) Candidates found it difficult to give acceptable answers to this question. Mass-energy conservation was rarely described. The idea that the mass of the reactants was greater than the mass of the products was seldom described. The link with the mass difference being converted to energy and being released in the reaction was described by a very small number of candidates.

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.

- Candidates should aim to make graphical work as clear as possible, with scales chosen to make finding points and interpreting gradient read-offs easy. Candidates should be discouraged from making the points fill the whole grid by using awkward scales, e.g. 0.57 : 1. All that is required is that the points occupy at least half of each axis, and a sensible scale, e.g. 10 : 1 or 4 : 1 or 0.5 : 1, can always be found to achieve this.

- When measuring a diameter it is good practice to repeat the measurement for different positions and then calculate the average. All raw readings should be recorded, even if they are the same.

- When using vernier calipers or a micrometer it is often useful to make a rough check of the measurement with a more familiar scale (such as a millimetre ruler). This can help avoid a power-of-ten error, such as recording 0.045 cm instead of 0.45 cm.

General Comments

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

The great majority of Centres had no difficulties in providing the equipment required for use by candidates. Supervisors should note that the experiment in **Question 2** is designed to have significant faults which candidates can identify and then go on to suggest practical improvements for. Supervisors who try to 'improve' the experiment so that it will work better for candidates on the day are doing them a disservice because it is then harder for them to find improvements.

Experiments are designed with the view that Centres will have the apparatus as outlined in the syllabus available for use. Any deviation between the equipment specified in the Confidential Instructions and that provided to the candidates should be written down in the Supervisor's Report. Any help given to the candidate should be noted on the Supervisor's Report. Supervisors are reminded that under **no circumstances** should help be given with the recording of results, graphical work or analysis.

Candidates did not seem to be short of time and both questions were attempted by almost all candidates. They demonstrated good skills in the generation and handling of data but can 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 investigate a system in equilibrium due to several turning forces.

Successful collection of data

(a) Most candidates recorded a value of *L* correctly, within the allowed range of 0.790–0.810 m. A few candidates recorded their answers in cm without changing the unit printed on the answer line (m).

(c) (ii) Many candidates recorded a value for *d* to the nearest mm (the precision of the metre rule); others only recorded their answer to the nearest cm, or did not take account of the unit printed on the answer line.

(d) Almost all candidates set up the experiment successfully and, without assistance, collected six sets of values of *m* and *d* showing the correct trend (*d* decreasing as *m* increases).

Range and distribution of values

(d) A small number of candidates made the best use of the range of masses available to them, including m = 10 g (or 0 g) and m = 100 g in their range of values; others chose a range of values between 10 g and 60 g or between 50 g and 100 g so lost credit for the range. Candidates are advised to include both the smallest and largest values possible when selecting the range of values for an experiment.

Presentation of data and observations

Table

(d) Most candidates were awarded the mark for using the correct column headings. Some either omitted the units for 1/*d* completely, or needed to include units of m^{-1} for the 1/*d* column rather than m. The majority of candidates gave the raw values of *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. Many expressed the values of 1/*d* to the same number of significant figures as (or one more than) the value of *d,* gaining credit. The great majority of candidates calculated values of 1/*d* correctly.

Graph

(e) (i) Candidates were required to plot a graph of 1/*d* against *m*. Some gained credit for drawing appropriate axes, with labels and sensible scales. Others chose to start the scale for the 1/*d* axis (the *y*-axis) at zero, leading to a compressed scale with all the points occupying much less than half the graph grid in the *y*-direction. Candidates can improve by checking that the first and last points, when plotted, occupy at least half the graph grid in both the *x* and *y* directions. This will sometimes mean starting the *y*-axis scale at a value other than zero. Many candidates gained credit for plotting their tabulated readings correctly. Others needed to draw plotted points so that the diameter is equal to, or less than, half a small square. A small point or a cross, drawn with a sharp pencil, is recommended.

(ii) Some candidates were able to draw a good line of best fit through six points. Others often joined the first and last points plotted, regardless of the distribution of the other points, or needed to rotate the line or move it sideways to give a better balance of points. If a point is being treated as anomalous for the purposes of drawing the best line, this should be indicated clearly on the graph e.g. by circling the suspect point (it is recommended that any anomalous point be checked by repeating the measurement).

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 $\Delta x/\Delta y$) 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). Some candidates correctly read off the *y*-intercept at $x = 0$ directly from the graph, gaining credit. 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. Many candidates correctly substituted a read-off into $y=mx+c$ to find the *y*-intercept. Others needed to check the point chosen was actually on the line of best fit and not just a point from 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)**, and recorded their values with appropriate units. 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 as the question specifically asks for the answers in **(e)(iii)** to be used to determine *P* and *Q*. Some candidates either gave incorrect units for *P* or *Q*, or omitted units completely. The correct units can be deduced from the axes of the graph or from the equation given in **(f)**.

(g) Many candidates were able to calculate *k* successfully (*k* should be 1.5; answers in the range 1.0 to 2.0 were given credit). Others made power-of-ten errors when substituting their values of *P, M* and *L* (e.g. combining g and kg, or millimetres and metres) or rearranged the equation given in **(g)** incorrectly.

Question 2

In this question, candidates were required to investigate the motion of a wooden rod supported by a string.

Successful collection of data

(a) (ii) Almost all candidates recorded a value for θ correctly, with a suitable unit, though a few omitted the unit. Some candidates lost the second mark as their value for θ was out of range ($72° \le \theta \le 92°$).

(b) Most candidates recorded a value for *T*, with units, in the range $1.0 \le T \le 2.0$ s for the first mark, though a few candidates mis-read the stopwatch, recording answers less than 0.1 s, or measured the time for half an oscillation. Most candidates also repeated their measurements, either by measuring the time for a single oscillation several times and finding an average, or by measuring the time *t* for several oscillations.

(c) (ii) Almost all candidates recorded a second value for θ and a second value for *T*.

Quality

(c) (ii) Almost all candidates found that the second value for *T* was less than the first value for *T*.

Display of calculation and reasoning

(a) (iv) Almost all candidates calculated sin θ correctly. A few candidates calculated sin θ with the calculator in radian mode so lost this mark.

(d) (i) The great majority of candidates were able to calculate *k* for the two sets of data, showing their working and so gaining credit. A few candidates either rearranged the equation incorrectly, or transcribed their values of *T* or sin θ incorrectly.

(d) (ii) Some candidates justified the number of significant figures used for *k* correctly, by linking the significant figures for *k* specifically to the significant figures for θ and *T*. Others linked *k* to sin θ or T^2, or compared the decimal places of *k* with θ and *T*, so lost this mark. A few very good candidates went further in their answers, stating, for example, that because θ and *T* were expressed to 2 significant figures, *k* could be expressed to 2 or 3 significant figures.

Analysis, conclusions and evaluation

(d) (iii) Some candidates were able to compare the percentage difference in their values of *k* by testing it against a specified percentage uncertainty, either taken from **(a)(iii)** or estimated themselves. Answers such as "the difference in the two *k* values is very large/quite small" are insufficient. Candidates are encouraged to calculate the percentage difference between the two *k* values and then make a judgement as to whether this is above or below what is expected. They should state what they think is a sensible limit for the percentage uncertainty for this particular experiment.

Estimating uncertainties

(a) (iii) Most candidates were familiar with the equation for calculating percentage uncertainty, though few made a realistic estimate of the absolute uncertainty (2° – 10°). 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.

Evaluation

(e) Many candidates scored less than half of the available marks in this section. The key to this section is for candidates to identify genuine problems associated with setting up this experiment and in obtaining readings, e.g. "the nail tends to slip in the bracket", or "the bracket moves when the oscillations start". Answers such as "difficult to read θ" receive no credit unless accompanied with some explanation as to why the difficulty arises e.g. "because it is hard to hold the protractor steady". Vague answers such as "ruler not accurate", "systematic error" or "parallax error" do not receive credit.

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 methods used for each solution, e.g. "fix the bracket to the bench with glue". Using a video camera and replaying the video is a good technique for measuring the time period of many different oscillations, but it should be made clear how the time measurement is actually made e.g. by using the clock function on the video, or by filming a stopclock next to the oscillation.

Credit is not given for suggestions that should be carried out anyway, such as repeating measurements and calculating averages or avoiding parallax errors by looking at an instrument 'square on'. Vague answers such as "turn fans off" or "use an assistant" are not usually valid.

PHYSICS

Paper 9702/32
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.

- Candidates should aim to make graphical work as clear as possible, with scales chosen to make finding points and interpreting gradient read-offs easy. Candidates should be discouraged from making the points fill the whole grid by using awkward scales, e.g. 0.57 : 1. All that is required is that the points occupy at least half of each axis, and a sensible scale, e.g. 10 : 1 or 4 : 1 or 0.5 : 1, can always be found to achieve this.

- When measuring a diameter it is good practice to repeat the measurement for different positions and then calculate the average. All raw readings should be recorded, even if they are the same.

- When using vernier calipers or a micrometer it is often useful to make a rough check of the measurement with a more familiar scale (such as a millimetre ruler). This can help avoid a power-of-ten error, such as recording 0.045 cm instead of 0.45 cm.

General Comments

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

Good answers in **Question 1** showed candidates were familiar with using a voltmeter and reading times correctly from a stopwatch. Good answers showed scales that spread the plots over more than half the graph grid, had a well-drawn straight line, and had read-offs at the corners of a large triangle to determine the gradient. The link was made correctly between gradient and intercept values and the constants in the equation.

In **Question 2** good answers showed candidates had recorded the diameter of the smaller tube. Strong candidates showed delicate manipulation of the apparatus and patience in counting the bubbles. Clear thinking produced good suggestions for methods of improved bubble counting and measurement of the small tube diameter.

Candidates can gain marks by being alert to units. In **Question 1**, the unit 'second' for time and the unit of $k\Omega\ s^{-1}$ for the constant *a* at the end of the question were important. The best answers used kΩ throughout as this was easier to manipulate by the candidates – Centres had been guided to label the resistor values in kΩ. In **Question 2** the tube diameter *d* needed a unit.

Comments on Specific Questions

Question 1

The experiment involved measurements of the time required for the voltmeter reading across a storage device to fall to a stated value as it discharged through an arrangement of resistors.

The majority of Centres had done well to set up the initial circuit and candidates were able to insert the resistors easily. Ensuring that all digital meters are in full working order can be a challenge and most Centres achieved this.

Successful collection of data

(b) Good answers showed candidates using a digital voltmeter with the 10.0 kΩ resistor to achieve a discharge time in the region of 14 s. Digital voltmeters were requested as these have the required resistance. Once candidates realised the unit was not given on the answer line, good answers included the unit. Generally candidates should be encouraged to repeat their readings and calculate the average time before moving on to the next part of the experiment.

Range and distribution of values

(c) Strong candidates used the full range of resistors. Time was well spent here to examine all the resistors and form a plan of which resistors to use in order to give as wide a range as possible.

Good answers had points lying close to the drawn line so the quality of the data was good when judged by the amount of scatter about a straight-line trend on the graph.

Presentation of data and observations

Table

(c) The majority of Centres have done well in teaching candidates how to present their raw readings clearly in a well drawn table. Candidates were able to tabulate their results for different values of the resistor *S* using appropriate column headings. Good answers showed candidates using the guidance in the question carefully and included values of *S*, *t*, 1/*S* and 1/*t* in the tables.

Good answers had column headings which included suitable units. Remembering to use the slash '/' to act as a separator between the quantity and the unit was important, for example $1/t$ / s^{-1} and $1/S$ / $k\Omega^{-1}$.

In good answers the values of *t* were all recorded to the same number of decimal places and values of 1/*t* were calculated correctly.

The number of significant figures in the calculated values of 1/S needed careful thought. When writing the calculated value the candidates did well when they used the number of significant figures in the original *S* value as their guide for the number of significant figures to give in their value of 1/*S*. For example when *S* = 1.0 kΩ (2 s.f.) the value for 1/*S* of 1.0 (2 s.f.) or 1.00 (3 s.f.) was acceptable, but not 1.000 (4 s.f.).

It appeared that when using *S* = 3.3 kΩ (2 s.f.), 1/S was often written as 0.303 (3 s.f.) which was acceptable, but candidates also gave *S* = 1.0 kΩ (2 s.f.) and 1/*S* as 1.000 (4 s.f.) to make the number of decimal places in the answer the same down the column. This was incorrect; the number of decimal places need not be constant down a column of calculated values.

If *S* = 22 kΩ (2 s.f.) then 1/*S* = 0.045 (2 s.f.) was correct but 1/*S* = 0.05 (1 s.f.) was not acceptable. When *S* was written as *S* = 22.0 kΩ (3 s.f.) then 1/*S* = 0.045 (2 s.f.) would be incorrect but 1/*S* = 0.0455 (3 s.f.) is correct. The zeros become very important.

Graph

(c) The standard of graph work was usually high, reflecting good preparation. Good answers showed candidates choosing "user-friendly" scales, i.e. scales that can easily be interpreted by someone examining the graph and checking points without needing to use a calculator. Ideally scales based on 2, 4, 5 or 10 should be used. Awkward scales based on 3, 6 or a scale where candidates make one large square worth, for example, 1.1 should not be used, nor should scales be used where one of the points lies off the printed grid.

Axes when drawn well are labelled every one or two large squares along the whole axis. Candidates should be advised to check that no values have been missed out, e.g. 0.1, 0.2, 0,4, 0,5 where the value 0.3 has been missed.

Good graphs have points spread over more than half the graph grid. If the points only occupy three large squares on the grid, candidates need to think again and work out a new scale.

Plotting of points in good answers was accurate. Candidates need care to ensure that very large dots as points (bigger than half a small square in diameter) are not produced as these will not gain credit. Good answers use a fine pencil producing points and a line thickness less than half a small square. In good answers all results in the table were plotted. Candidates should understand that missing a point out as it lies off the grid will lose credit.

Good answers showed a well drawn straight line. Candidates need to understand how to draw a line so that all the points have a fair balance along the whole line and practice drawing this type of line. Candidates may find it helpful during practice sessions to draw a thin line on a piece of acetate sheet and spend some time angling the line to get an understanding of where the best line lies. Often a better line can be drawn by rotation of the original line.

Analysis, conclusions and evaluation

Interpretation of graph

(d) Good responses showed candidates had been well prepared on how to find the gradient and intercept values of a straight line graph. For the gradient a large triangle was chosen where the hypotenuse used was longer than half the length of the drawn line, and read-offs were accurately taken from points which lay on the line. Candidates looking for points on the line that could be read off easily produced good answers, but using table values often led to the use of points that did not lie on the drawn line.

Good answers used read-offs correctly, with clear working showing $\Delta y/\Delta x$, before writing the calculated value of the gradient on the answer line. The intercept was correctly calculated by substituting read-offs, from a point which lay on the line, into the equation $y = mx + c$. Some good answers showed that if the x-axis included the value $x = 0$, then the intercept could be directly read from the graph.

In finding the y-intercept, candidates need to understand that they should calculate the y-intercept rather than choosing to extend the line below the grid in an attempt to estimate a read-off. This inaccurate method will not gain credit.

Drawing conclusions

(e) Good answers showed a clear understanding of how the values found for gradient and intercept in **(d)(iii)** related to constants a and b where a = gradient and b = (value of intercept / value of gradient). Good answers showed the correct rearrangement.

The exact values from **(d)(iii)** should be used with no recalculation. Candidates need to understand that it is not necessary to do any new calculations, e.g. simultaneous equations.

The best answers included the correct units, e.g. the correct unit for a was $\mathrm{k\Omega\,s^{-1}}$ or $\mathrm{\Omega\,s^{-1}}$, whichever was appropriate. Candidates need to understand how to work out the units of the constants in an equation.

Question 2

This experiment investigated the volume of an air bubble produced in water by tubes of different internal diameter. The experiment demanded a gentle, continuous pushing force on the syringe whilst counting the number of bubbles produced. The best answers showed repeat readings of the tube diameter. Candidates have time to take repeat readings and should be encouraged to do so. The diameter measurement was very difficult owing to its small size and the challenge of using the vernier calipers to measure such a small distance.

The best answers showed that, while doing the experiment, there had been thought about why it was difficult to take accurate readings. Thinking about difficulties during the experiment will make answering the final part **(g)** much easier.

Successful collection and presentation of data

(a) (i) Good answers showed candidates had made a good attempt to measure the tube diameter and repeat the reading, stating the answer with the unit mm or cm. These candidates appreciated just how small a distance was being measured, i.e. between 1 or 2 mm. Thinking about whether the final answer was sensible helped many candidates avoid the pitfall of writing incorrectly 1 cm rather than 1 mm. Those experienced in reading the scale of vernier calipers and familiar with the conversions between mm, cm and m had a distinct advantage.

(c) (i) Candidates familiar with reading a syringe coped well with noting the first volume reading.

(ii) Good answers showed that candidates had recorded the number of bubbles produced and read the new volume of air in the syringe.

(e) Good answers showed that candidates had removed the smallest tube and done the experiment with the larger tube. These candidates tended to notice that there were only two tube sizes available and were able to suggest in **(g)(i)** that this was a limitation.

Stronger candidates found that a larger diameter tube gave a bubble with larger volume. Candidates had plenty of time to take readings from the syringe so could place their heads in the correct position – meaning there would be no parallax error involved. Consequently this would not be a significant source of error for **(g)(i)**.

Estimating uncertainties

(a) (ii) Good answers showed calculation of the percentage uncertainty of the *d* value, showing the method.

Being so difficult to measure the diameter, it was appropriate to use at least 0.2 mm for the absolute uncertainty when finding the percentage uncertainty. The best candidates estimated between 0.2 and 0.5 mm. It was right to decide not to use the minimum scale division on the vernier calipers or ruler.

Display of calculation and reasoning

(c) (iii) This was usually calculated correctly.

(d) Good responses justified the number of significant figures in V in terms of n and $(r_1–r_2)$, not just "the raw readings" or r_1 and r_2 on their own.

(f) (i) Good answers showed clear working and two correctly calculated values of k, with the equation correctly rearranged to find k not $1/k$. A common error was to find $V^3 \times d^2$ rather than V^3/d^2.

Analysis and conclusions

(f) (ii) Candidates should calculate the percentage difference between the two k values, state a percentage value they will use as a criterion for comparison and then use this criterion to decide if the relationship is valid or not. It is helpful for the candidates to refer to percentage uncertainty rather than using the term "experimental accuracy".

For the stated criterion, good answers used the percentage uncertainty found earlier in the question. Strong candidates made a comparison. If the percentage difference between the two *k* values is less than the stated criterion, then the relationship is supported. Candidates should understand that if the value of the percentage difference is greater than the value stated as the criterion, then the relationship is not supported and the candidate needs to state this e.g. "the relationship is not supported".

Candidates need to understand that stating the difference between the two *k* values is "small" or "large" is not sufficient. Candidates also need to understand that using rounding to 'make' the *k* values equal is not good enough. In good answers, the *k* values were found to 3 s.f. and these were used to find the percentage difference.

Evaluation

(g) Good answers suggested detailed, relevant limitations and improvements. The best answers were characterised by detailed suggestions specific to this experiment with the major challenges being measurement of the tube diameter and counting the bubbles.

Candidates need to understand that general vague ideas such as 'zero errors', 'systematic errors' or 'parallax errors' with no link to the experiment will not be credited. In this experiment parallax errors related to the syringe were not relevant.

Many good answers were characterised by including the suggestion that "only two sets of readings for two different diameters were taken". The improvement given in good answers was to "take more readings with a wider variety of *d* values and plot a graph". Candidates need to understand that "take more readings", which could have the meaning of more repeat readings, or merely suggesting taking the average, are not sufficient.

In the improvements section there is no credit for the idea of repeating readings. During the experiment candidates should write down their repeated measurements and good answers gained credit early in **Question 2** for repeats.

Also here the best answers tackled the difficulty of measuring the diameter of the small tubes. Good answers showed an appreciation that it was difficult to measure the tube diameter because the jaws of the vernier calipers would not fit inside the tube or distorted the tube. A good answer for the improvement would propose a different method for measuring the small diameter, such as a travelling microscope. A different method of measurement is needed – suggesting the use of new tubes made from different materials (flexible or rigid) or larger diameter tubes does not gain credit.

With limitations in **(g)(i)** each of the statements in good answers has two parts - firstly the limitation (or difficulty) is stated, secondly this is expanded giving the reason why making the measurement is difficult. For example a good answer could state "it was difficult to count the bubbles [limitation] because they came out too close together [reason]". Just giving the first part of the sentence without the reason, i.e. "it was difficult to count the bubbles", is not sufficient to be credited.

The corresponding improvement in good answers suggested using a video to record the bubbles then to play back the video to note the number of bubbles. Candidates need to understand the difference in meaning between stating "the bubbles will be videoed and played back" and stating "take a slow motion video". The video is not taken in slow motion; it is the replay which is done at a slow frame rate and this is the improvement. Good answers showed candidates understood the need for detail. A statement "use a video" is not sufficient – relevant detail is needed.

Specific suggestion of a different method to make a measurement featured in good answers. Realising that it was difficult to control the syringe in order to produce a slow, steady stream of bubbles, vague answers suggested "use a machine to control the syringe" or "a simple device to apply a small constant force" realising what is needed but not being specific. Answers that are more specific are needed.

PHYSICS

Paper 9702/33
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.

- Candidates should aim to make graphical work as clear as possible, with scales chosen to make finding points and interpreting gradient read-offs easy. Candidates should be discouraged from making the points fill the whole grid by using awkward scales, e.g. 0.57 : 1. All that is required is that the points occupy at least half of each axis, and a sensible scale, e.g. 10 : 1 or 4 : 1 or 0.5 : 1, can always be found to achieve this.

- When measuring a diameter it is good practice to repeat the measurement for different positions and then calculate the average. All raw readings should be recorded, even if they are the same.

- When using vernier calipers or a micrometer it is often useful to make a rough check of the measurement with a more familiar scale (such as a millimetre ruler). This can help avoid a power-of-ten error, such as recording 0.045 cm instead of 0.45 cm.

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

Candidates did not seem to be short of time and both questions were attempted. 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) Most candidates measured the diameter *d* within range to the nearest 0.01 mm consistent with units. The most common error was in the reading of the micrometer screw gauge (0.75 mm instead of 0.25 mm).

(b) (v) Most candidates stated an appropriate length and voltage. Other candidates needed to think whether their answer was realistic or not (e.g. 50 m or 350 V) given that units were provided. The most common error was confusing cm with m and mV with V.

(d) Most candidates were able to set up the experiment without assistance and collect six sets of values for l and V. Some candidates collected data giving the wrong trend owing to mis-reading the metre rule.

Range and distribution of values

(d) Many candidates did not extend the range of readings of l over at least 60.0 cm. Candidates could have made better use of the available range of wire provided. Some candidates started mid-way along the wire and increased the length measurement to the maximum, whilst others reduced the length measurement from mid-way to the minimum length possible. In both cases, this did not provide the range required.

Presentation of data and observations

Table

(d) Many candidates were able to include correct units with the column headings including $1/l$ / m^{-1} and V/l / $V m^{-1}$. Some candidates wrote the column heading $1/l$ or V/l omitting a unit, or omitted a separating mark between the heading and unit. A few candidates omitted the V/l column entirely. 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, and record answers to the nearest mm instead of to the nearest cm. Those candidates stating length in m often excluded the zero in the cm and mm place, failing to gain credit (e.g. 0.3 m instead of 0.300 m). A few candidates stated l values in the $1/l$ column. Many candidates were able to calculate V/l correctly, but others incorrectly calculated Vl or V/l instead.

Graph

(e) (i) Candidates were required to plot a graph of V/l against $1/l$. Some candidates drew graphs giving an incorrect trend, perhaps because $1/l$ was actually l instead (calculating $l/1$ instead of $1/l$). Many candidates gained credit for drawing appropriate axes with labels. Some candidates chose awkward scales that were either linear (going up in threes or sixes) or non-linear. 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 is essential for this. The plotting of graphs would be improved by drawing points with a diameter equal to, or less than, half a small square and by plotting the points to an accuracy of within half a small square. Many candidates rounded down their values in the table and plotted the points to one or two significant figures, losing credit for quality of results.

(e) (ii) Some candidates were able to draw a good line of best fit through six points. 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). Some candidates needed to rotate lines to give a better fit or move lines 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 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 is large enough (the hypotenuse should be at least half the length of the line drawn and can be longer). A few candidates drew a suitable triangle but 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) for this method of finding the y-intercept to be valid. Some candidates drew a negative y-axis scale to fit on the grid at $x = 0$, gaining credit for reading directly from the graph. Other candidates extended a negative y-axis off the graph grid and extrapolated the line off the graph grid, and this did not gain credit. It is expected that candidates will use only the graph grid; plotting and extrapolation outside the grid are not accepted. 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 M was equal to the value of the gradient and N was equal to the negative value of the intercept calculated in **(e)(iii)** for the first mark. Others tried to calculate M and N 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 to determine M and N.

(f) (ii) Few candidates stated their previous answers to **(a)(ii)**, **(b)(vi)** 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.

Question 2

In this question, candidates were required to investigate how the loss of gravitational potential energy of a rolling ball depends on its initial height.

Successful collection of data

(a) (ii) Most candidates recorded a value of H with consistent units.

(b) (ii) Some candidates recorded a value of h_1 to the nearest mm and with a unit. Many candidates stated h_1 to the nearest cm, failing to gain credit as the ruler can be read to the nearest mm. A few candidates stated h_1 to the nearest tenth of a millimetre, failing to gain credit.

(c) (iii) Most candidates recorded a value of h_2 less than h_1. Many candidates failed to repeat their h_2 reading, and some repeated the static reading h_1 instead. It is expected that candidates identify the most unreliable reading and then repeat it. In this experiment the most unreliable reading was h_2 as the height the ball reached is always different whereas h_1 can be fixed.

(e) Many candidates recorded a new value for h_1 and h_2 for the ball released from a lower starting height.

Quality

(e) Most candidates found that the lower the starting position of the ball, the smaller the value of the maximum height the ball rolled up on the opposite ramp.

Presentation of data and observations

Display of calculation and reasoning

(d) Most candidates were able to calculate F, but many candidates did not realise that F did not have units.

(f) (i) Many candidates were able to calculate $k = F^3h$ correctly for both experiments. A few candidates calculated F^3/h or Fh instead, and did not gain credit.

(f) (ii) Few candidates were able to relate the number of significant figures in k to the significant figures used in h_1 and $(h_1 - h_2)$. Some candidates related to just one quantity or to the 'raw data' without specifying the quantities used, referred to the 'distance' without specifying which distance, or to '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 **(b)(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 mm). Most candidates stated the uncertainty as 1 mm, the smallest reading on the ruler. Candidates should recall that the absolute uncertainty in the value of h_1 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 h_1 is difficult to judge: the bottom of the ball is hard to locate as the edge of the ramp could block the view. Where measurements have been repeated, an acceptable method to estimate the absolute uncertainty is to calculate half the range of the results and use this as the absolute uncertainty. This was commonly used, but a few candidates forgot to halve the range.

Evaluation

(g) Many candidates found this section difficult. 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 height" is insufficient to gain credit. An explanation such as "it is difficult to measure h_2 because the ball stayed at h_2 for a very short interval of time" would be acceptable. Confusing statements also failed to gain credit, e.g. "the ball was too quick to measure h_2" (the ball was actually stationary at h_2).

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. "the ball lost energy at the joining of the ramps". They can improve their answers by stating the methods used for each solution e.g. "join the ramps with tape to make a continuous surface". In doing this, candidates should look at how each solution helps and improves this particular experiment. Some candidates came up with some novel approaches which were credited, e.g. "place ball in chalk so when it rolls you can see the trace on the track".

Weaker candidates referred to using a camera without being specific as to what this will be used for. Candidates should be encouraged to describe a video with a clamped ruler in the picture so that the height of the end point can be decided more accurately. Credit is not given for suggestions that should be carried out anyway, such as repeating measurements and calculating averages or avoiding parallax errors by looking at the ruler and ball 'square on'. Vague answers such as "turn fans off" or "use an assistant" are not usually valid.

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.

- Candidates should aim to make graphical work as clear as possible, with scales chosen to make finding points and interpreting gradient read-offs easy. Candidates should be discouraged from making the points fill the whole grid by using awkward scales, e.g. 0.57 : 1. All that is required is that the points occupy at least half of each axis, and a sensible scale, e.g. 10 : 1 or 4 : 1 or 0.5 : 1, can always be found to achieve this.

- Common causes of lost credit in graph work are plotting 'blobs' (points with diameter greater than half a small square) and drawing thick or kinked lines of best fit. Using a sharp pencil and a transparent 30 cm ruler makes it much easier to plot points accurately and draw a good line of best fit.

- Candidates should always think about the precision of their recorded measurements. These should be to the smallest division of the measuring equipment used (e.g. 0.1 cm for a ruler, 0.01 mm for a micrometer, etc.) and no more. This precision should be shown even when the experimenter can select his/her own values (so lengths of wire of exactly 20 cm and 30 cm should be recorded as 20.0 cm and 30.0 cm when measured with a ruler).

General Comments

Centres reported few problems with providing the necessary apparatus for the two questions. 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 the candidate should be noted on the Supervisor's Report. Supervisors are reminded that under **no circumstances** should help be given with the recording of results, graphical work or analysis.

After the initial setting up of apparatus, **Question 1** proved straightforward for the majority of candidates. In **Question 2** many showed sound reasoning when deciding how many significant figures to include in calculations, and when deciding if their evidence supported the suggested relationship.

Candidates had time to complete both questions and in most cases the instructions were understood and followed carefully. There was variation between Centres, producing a wide range of marks. Many Centres had prepared candidates well and this often led to good scores in both questions.

Comments on Specific Questions

Question 1

In this question, candidates were required to investigate the forces on a loaded beam.

Successful collection of data

(b) (i) Most answers included a sensible initial value for *d*, showing that the apparatus had been set up correctly. A few omitted the unit.

(c) Nearly all candidates recorded results for six different values of *d*, in most cases with a trend correctly showing *F* decreasing with increasing *d*.

Range and distribution of values

(c) The apparatus allowed for *d* to vary from 24 cm to 74 cm and good candidates used a suitably large part of this range (30 cm or more).

Table

(c) Tables were generally neat and clear. In good answers the headings included units separated from their quantity by using a solidus (/) or by using brackets, e.g. $1/d$ (m^{-1}) or $1/d$ / m^{-1}.

Strong candidates correctly recorded all their values of *d* and *F* to the precision of their instruments (0.1 cm for *d* and 0.1 N for *F*). Weaker candidates often added an extra zero to all readings (e.g. 2.10 N, 3.70 N, 5.20 N etc.).

Calculations were done well although, in many cases, too few significant figures were given. Candidates should remember that leading zeros (including those after a decimal point) do not count towards significant figures (e.g. 0.029 cm^{-1} has only 2 significant figures).

Graph

(d) There were many good graphs with simple scales and all points from the table clearly 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.

A few graphs filled the entire grid by using very awkward scales. It is only necessary to use at least half the grid in each direction. The awkward scales lose credit and often lead to mis-reading of coordinates.

Most candidates' quality of results (as indicated by scatter on the graph) was good.

Lines of best fit were usually clearly defined, and some candidates indicated that they were ignoring an outlying point by circling it.

Interpretation of graph

(d) Most Centres had prepared candidates well. In good answers a large triangle was added to the graph to indicate the coordinates used to calculate the gradient, and the calculation itself was presented clearly.

In this experiment the *y*-intercept had a value less than zero and so it had to be calculated unless the candidate chose to include a negative section of the *y*-axis. A small number of candidates mistakenly took the value where the trend line crossed the *x*-axis. Others tried to extrapolate their line off the grid, and this was not credited.

Drawing conclusions

(e) The majority of candidates identified the values of the constants *a* and *b* as their gradient and intercept values.

Many candidates gave correct units for *a* and *b*, though in a few cases the unit for *a* did not correspond to the units used earlier in the experiment (e.g. *a* = 245 N m instead of 245 N cm).

Question 2

In this question, candidates were required to find the speed of water flowing through a tube.

Successful collection of data

(a) Several candidates had difficulty with the power of ten in their measurement of the internal diameter *D* of the tube. They were provided with vernier calipers and a value in cm was required, but some candidates recorded around 0.040 cm or even 4.0 cm instead of the 0.40 cm value expected.

Only a few very good candidates recorded repeat measurements of *D*. This is important for a cross-section that is possibly not circular.

(c) (i) Most candidates recorded a sensible value for the tube length *l*, although a few used incorrect precision (e.g. 20.00 cm).

(iii) The flow timing to give *t* was generally well done, with only a few cases of misinterpreting the stopwatch display (e.g. interpreting 00:04:37 as 0.0437s).

(e) Nearly all candidates recorded the expected result of a longer time for a shorter tube.

Estimating uncertainties

(a) (ii) Candidates were asked to measure the internal diameter of a plastic tube using vernier calipers. Good candidates realised that the flexibility of the plastic led to distortion so the absolute uncertainty was greater than the precision of the calipers, i.e greater than 0.01 cm.

Display of calculation and reasoning

(c) (iv) In nearly every case the candidate correctly calculated the value for *v*.

(d) A large number candidates explained clearly that the significant figures given for *v* depend on the quantities used in the calculation, and correctly listed both *D* and *t*. 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,* with only a few rounding errors or mistakes in rearranging the equation.

Drawing conclusions

(f) (ii) Candidates from many Centres produced a clearly reasoned conclusion from their results, such as "the percentage difference between *k* values is less than 10% so the relationship is valid". Weaker answers were too vague, e.g. "there is a large difference between *k* values".

Evaluation

(g) In the Limitations section the good candidates stated a problem and explained the cause (e.g. "measuring the tube length was difficult because it curled up"). Most candidates identified the difficulty in seeing the water level and also the fact that only two tube lengths were tested. The stronger candidates described how the tendency of the tube to curl caused difficulties with making it hang vertically. Measuring the tube diameter was also a problem as using the calipers caused distortion (a non-contact method such as using a travelling microscope would have avoided this). Only very good answers gave an adequate description of the difficulty in timing, i.e. in operating the stopwatch exactly at the moment when the level passed the syringe graduation. Many answers mentioned parallax but this experiment presented no significant problems with parallax.

In the Improvements section many candidates identified the potential benefit of colouring the water to make it more visible. Others suggested using a video recorder with a timer included in the picture, but most suggestions of light gates or other sensors for timing did not include sufficient detail about their positioning. Many candidates wanted to change the tube to a straight and rigid type, but this would have changed a fundamental part of the experiment and would not be appropriate — it is generally possible to use different measuring equipment, and sometimes a length or a timing interval can be increased to improve uncertainties, but the materials being tested should not be changed.

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.

- Candidates should aim to make graphical work as clear as possible, with scales chosen to make finding points and interpreting gradient read-offs easy. Candidates should be discouraged from making the points fill the whole grid by using awkward scales, e.g. 0.57 : 1. All that is required is that the points occupy at least half of each axis, and a sensible scale, e.g. 10 : 1 or 4 : 1 or 0.5 : 1, can always be found to achieve this.

- When measuring a diameter it is good practice to repeat the measurement for different positions and then calculate the average. All raw readings should be recorded, even if they are the same.

- When using vernier calipers or a micrometer it is often useful to make a rough check of the measurement with a more familiar scale (such as a millimetre ruler). This can help avoid a power-of-ten error, such as recording 0.045 cm instead of 0.45 cm.

General Comments

The general standard of the work done by the candidates was good.

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

Candidates did not seem to be short of time and both questions were attempted. 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 investigate how the motion of an oscillating system depends on the mass attached to the system.

Successful collection of data

(a) (ii) Most candidates measured several complete swings and determined a value for one complete swing T in the correct range. The most common error was that T was too small, perhaps because candidates had measured half a swing.

(b) The majority of candidates were able to set up the experiment without assistance and collect six sets of values for m and T.

Range and distribution of values

(b) Many candidates did not extend the range of readings of m over at least 0.600 kg. Candidates should be encouraged to make full use of the equipment available in order to achieve a wide range of values.

Presentation of data and observations

Table

(b) Many candidates were able to include correct units with the column headings including $1/T^2$ / s^{-2}. Some candidates wrote the column heading $1/T^2$ without a unit, or omitted the separating mark between the heading and unit. Many candidates were able to relate the significant figures in the calculated quantity $1/T^2$ to the number of significant figures in T. Many candidates were able to calculate $1/T^2$ correctly. Some candidates calculated $1/T$ or $T^2/1$ instead.

Graph

(c) (i) Candidates were required to plot a graph of $1/T^2$ against m. Many candidates gained credit for drawing appropriate axes with labels and sensible scales. A few candidates chose awkward scales that were linear (going up in threes or sixes) or non-linear. 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 is essential for this. The plotting of graphs would be improved by drawing points with a diameter equal to, or less than, half a small square and by plotting the points to an accuracy of within half a small square.

(c) (ii) Some candidates were able to draw a good line of best fit through six points. 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). Some candidates needed to rotate lines to give a better fit or move lines 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 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

(c) (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 is large enough (the hypotenuse should be at least half the length of the line drawn and can be longer). A few candidates drew a suitable triangle but 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) for this method of finding the y-intercept to be valid.

Drawing conclusions

(d) 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 **(c)(iii)** for the first mark. 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 as the question specifically asks for the answers in **(c)(iii)** to be used to determine P and Q.

Question 2

In this question, candidates were required to investigate how the force required to raise a straight wire from water depends on its length.

Successful collection of data

(a) (i) Most candidates recorded a value of L in range with consistent units to the nearest mm. Common errors included omitting the units or stating L to the nearest cm or tenth of a millimetre.

(b) (iii) All candidates recorded a value of N_1 as an integer.

(c) (iii) Most candidates recorded a value of N_2 greater than N_1. Many candidates did not repeat their readings of N_1 or N_2.

(e) Most candidates recorded a new value for L, N_1 and N_2 for the longer wire.

Quality

(e) The majority of candidates found that the longer the wire, the greater the number of paperclips required to make the wire move upwards.

Presentation of data and observations

Display of calculation and reasoning

(d) Most candidates were able to calculate F. A common error here was to equate m to the mass of all the paperclips used instead of just one.

(f) (i) Many candidates were able to calculate k correctly. A minority of candidates calculated FL instead.

(f) (ii) Few candidates were able to relate the number of significant figures in k to the significant figures used in L and ($N_1 - N_2$). Other candidates related the number of significant figures to just one quantity or to "the raw data" without specifying the quantities used, or to "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 **(a)(ii)** 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

(a) (ii) Most candidates were familiar with the equation for calculating percentage uncertainty and many candidates made a realistic estimate of the absolute uncertainty (1 – 3 mm). Where measurements have been repeated, an acceptable method to estimate the absolute uncertainty is to calculate half the range of the results and use this as the absolute uncertainty. This was commonly used, but a few candidates forgot to halve the range.

Evaluation

(g) Many candidates scored less than half of the available marks in this section. 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 number of paperclips" is insufficient to gain credit without an explanation.

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 difficulties encountered during the experiment, e.g. "can only measure in multiples of paperclips (0.4 g)". They can improve their answers by stating the methods used for each solution e.g "use smaller masses than paperclips e.g. riders or graph paper". In doing this candidates should look at how each solution helps and improves this particular experiment.

PHYSICS

Paper 9702/41

A2 Structured Questions

Key Messages

- Many candidates were better at performing mathematical calculations than constructing answers using sentences of continuous prose. It is important for candidates to practise answering questions that require them to write complete sentences, and ensure that these closely focus on the question being asked.
- A general weakness amongst candidates occurs where explanation of some aspect of physics is required. This weakness is also carried over to the explanation of calculations. Candidates would benefit greatly from practice at explaining their work so that it becomes natural to them to give fuller answers to questions, thus avoiding the unnecessary loss of credit.
- Candidates should be reminded that credit is not only awarded for final answers, but also for the approach to problems. Numerical working should therefore be accompanied by an adequate level of explanation. This explanation may gain some credit even if the numerical work is incorrect.

General Comments

Accurate recall of laws and definitions is fundamental to a good performance in the examination.

There was no real evidence amongst adequately prepared candidates of a shortage of time.

The candidates produced a wide range of responses and most questions provided good differentiation. The paper challenged the most able candidates, but was also accessible to those who were less able.

Comments on Specific Questions

Section A

Question 1

(a) It was generally understood that a gravitational field is a region of space where a mass experiences a force. A small minority of answers gave an inappropriate definition of gravitational field strength.

(b) (i) With few exceptions, a basic statement of Newton's law of gravitation was given. Relatively few answers included the condition that the law applies to point masses.

(ii) Although most answers included the correct expression for gravitational field strength, two common errors were evident in the ensuing calculation of the ratio. These were calculating the inverse of the required ratio and not squaring the radii of the orbits.

(c) (i) The derivation of the expression for the mass of the Sun often consisted of pure algebraic working without any accompanying explanation. Those answers that did contain an explanation often stated that the gravitational force on the Earth is equal to the centripetal force, possibly implying that there is an equilibrium situation. It is more accurate and less ambiguous to explain that the gravitational force provides the centripetal force.

(ii) Although the calculation was a straightforward one, candidates needed to ensure that the radius of the Earth's orbit was converted from units of km to m.

Question 2

(a) An ideal gas is one that obeys the equation pV/T = constant for all values of pressure, volume and thermodynamic temperature. It was not sufficient to simply state one or two assumptions of the kinetic theory of gases.

(b) (i) The calculation caused few problems, although a small minority of answers contained a power-of-ten error in the value of the volume.

(ii) In order to determine the final temperature, it was necessary to apply the ideal gas equation to the total amount of gas. A common error was to apply the ideal gas equation to the gas in only one cylinder without realising that the amount of gas in that cylinder changes when the tap is opened.

(c) The majority of answers contained vague statements such as "work is done on the system". More precise wording was needed. When the tap is opened, gas passes from cylinder B to cylinder A. Work is done on the gas in cylinder A, causing an increase in internal energy and hence an increase in temperature.

Question 3

(a) The vast majority of answers to **(i)** and **(ii)** were fully correct.

(b) There were many incorrect graph shapes such as sinusoidal curves. The correct graph is a straight line with a negative gradient that passes through the origin. Candidates needed to ensure that they used reasonable scales and then accurately plotted the end points of the line.

(c) Different methods of calculation were possible. The simplest was to realise that the kinetic energy would be equal to the potential energy, thus enabling a general expression for potential energy to be equated to an expression for one half of the maximum kinetic energy. Candidates needed to adequately explain their chosen method of calculation.

Question 4

(a) This part of the question presented few problems for the well-prepared candidate. Reference must be made to a "unit positive charge" in the stated definition.

(b) Candidates should always explain any algebraic expressions that are used in a derivation. In this case they needed to explain that the kinetic energy of the charged particle is equal to its loss of potential energy.

(c) Most candidates used the expression given in **(b)** to calculate either the particle's speed or the electric potential of the sphere for the condition that the particle just reaches the surface of the sphere. They could then compare the calculated value of their chosen quantity with its actual value stated in the question. The most common approach was to calculate the particle's speed, although this was often wrongly interpreted as being its speed at the surface of the sphere.

Question 5

(a) Candidates need to be able to distinguish between the definition of a quantity and the definition of a unit. The tesla is a unit and so it should be defined in terms of the metre, the newton and the ampere. Candidates should also refer to force per unit length being one newton per metre, rather than a force of one newton on one metre length of wire.

(b) (i) Almost all answers were fully correct, although a small minority confused the permeability of free space with the permittivity of free space.

(ii) Some candidates were not able to distinguish between flux linkage and flux.

(c) (i) Faraday's law of electromagnetic induction was usually quoted correctly.

(ii) The most common error was to calculate an average e.m.f. that corresponded to the current in the solenoid being switched off, rather than being reversed.

Question 6

(a) (i) Candidates were expected to refer to the reduction of power loss in the core due to eddy currents. A common error was to believe that power loss and eddy currents are prevented rather than reduced.

(ii) An ideal transformer is one that has no power loss, so that the input power is equal to the output power.

(b) The calculation was usually done correctly, although a significant minority of candidates did not convert the root-mean-square voltage to a peak voltage.

Question 7

(a) (i) Many candidates stated that the threshold frequency is the minimum frequency for an electron to be emitted from the surface, without making it clear that it is the minimum frequency of electromagnetic radiation.

(ii) The vast majority of calculations were successful.

(b) A variety of approaches were possible. Some candidates calculated the frequency corresponding to a wavelength of 300 nm and compared this to the threshold frequencies of the metals. Others calculated the energy of a 300 nm photon and compared this to the work function energies of the metals. A small minority successfully calculated the threshold wavelengths of the metals and compared these to the wavelength of 300 nm.

(c) Although many candidates realised that a higher frequency would result in each photon having more energy, very few of these candidates went on to deduce that there must be fewer photons per unit time in order to maintain the same intensity. Thus, there is a decrease in the rate of emission of electrons. Most candidates had the false impression either that the rate of emission of electrons would stay the same because the light intensity is the same or that the rate of emission of electrons would increase because the electrons are emitted with more kinetic energy.

Question 8

(a) In nuclear fusion, two light nuclei combine to form a more massive nucleus. Candidates should use the correct terms in their statements. A nucleus should not be confused with an element, molecule, atom, nucleon or nuclide.

(b) (i) Most answers correctly calculated the change of mass in u and also stated the equation $E = mc^2$. However, the calculation of the released energy often contained arithmetic errors or omitted the conversion of the mass units from u to kg.

(ii) The reason for needing a high temperature was seldom understood. It is to ensure that the kinetic energies of the proton and the deuterium nucleus are large enough to enable them to overcome their mutual electrostatic repulsion.

Section B

Question 9

(a) Suitable sensing devices were usually suggested.

(b) (i) Most answers correctly stated that the resistance of the thermistor decreases and that V_{OUT} increases. However, very few answers explained why the decrease in thermistor resistance causes V_{OUT} to increase.

(ii) Although many candidates stated that the change in V_{OUT} varies non-linearly with the change in temperature, very few could give a reason for this. One reason is that the change in thermistor resistance varies non-linearly with the change in temperature. Another reason is that the change in V_{OUT} varies non-linearly with the change in thermistor resistance.

Question 10

(a) It was generally understood that sharpness relates to how well the edges of structures are defined. However, only a small minority of candidates appreciated that contrast relates to the difference in the degree of blackening between structures. Statements such as "contrast is the amount of blackening of the image" are incomplete and did not gain credit.

(b) Some candidates listed factors that merely affect sharpness rather than specifically cause a *loss* of sharpness. The most commonly stated correct causes were the scattering of photons in tissue, a large area anode and a large aperture through which the beam passes. A significant minority of candidates referred to causes of loss of contrast rather than loss of sharpness.

(c) (i) Most candidates could recall the appropriate equation, although power-of-ten errors were common and sometimes the inverse of the correct ratio was calculated.

(ii) The answer given here needed to be consistent with the value of the ratio calculated by the candidate in **(i)**. Explanations were often rather vague. A common misconception is that contrast is solely determined by the difference in the linear attenuation coefficients.

Question 11

(a) (i) A precisely worded statement was needed. The amplitude of the carrier wave varies in synchrony with the displacement of the information signal.

(ii) The most commonly-stated correct reasons for transmitting a modulated wave were that it would have less attenuation, a greater range and less interference from other radio waves. Another important advantage is that it will enable the use of a smaller aerial. Some candidates did not make it clear whether their comments referred to the modulated radio wave or the information signal radio wave.

(b) (i) There was considerable confusion here with many candidates basing their calculation on an incorrect carrier wave frequency of either 900 kHz or 909 Hz.

(ii) Most answers were correct.

(iii) There were few successful answers. The most common incorrect answers were 9 Hz and 918 kHz.

Question 12

A significant number of candidates had clearly practised this type of calculation and were able to obtain full marks. There were also many candidates who had difficulty in applying the appropriate equations. Common errors included having the power ratio the wrong way round, using logs to the base e and having power-of-ten errors in the substituted values of power. In **(b)**, a small minority of answers confused attenuation with gain so that the calculated attenuation had an inappropriate negative value. Some answers had an unreasonable order of magnitude. In such instances, candidates should be encouraged to re-check their calculations as they may be able to quickly identify an error in their working.

PHYSICS

Paper 9702/42

A2 Structured Questions

Key Messages

- Many candidates were better at performing mathematical calculations than constructing answers using sentences of continuous prose. It is important for candidates to practise answering questions that require them to write complete sentences, and ensure that these closely focus on the question being asked.

- A general weakness amongst candidates occurs where explanation of some aspect of physics is required. This weakness is also carried over to the explanation of calculations. Candidates would benefit greatly from practice at explaining their work so that it becomes natural to them to give fuller answers to questions, thus avoiding the unnecessary loss of credit.

- Candidates should be reminded that credit is not only awarded for final answers, but also for the approach to problems. Numerical working should therefore be accompanied by an adequate level of explanation. This explanation may gain some credit even if the numerical work is incorrect.

General Comments

The marks scored by candidates ranged widely. For many candidates, there was a noticeable difference between the percentage of marks scored in Section A when compared with that attained in Section B. In order to perform well in the examination, it is essential that candidates have a thorough understanding of the syllabus content assessed in Section B. Section B comprises 30 out of the 100 marks, and very many candidates would benefit from further study of this section.

Well-prepared candidates seemed to have adequate time to complete their answers.

Comments on Specific Questions

Section A

Question 1

(a) There were many comprehensive answers but it was common for some aspect, such as direction of motion or time period, to be omitted. There were some answers where no reference was made to the Earth. Also, stating that the satellite has the same "period of rotation" is ambiguous.

(b) Many answers commenced by stating two equations, equating gravitational force to centripetal force. Explanation was expected and, in this situation, candidates should have stated that the gravitational force provides the centripetal force for circular motion.

(c) This was generally well done but, in a significant number of scripts, marks were lost through carelessness. For example, *T* was not converted to seconds or was not squared. Candidates should be encouraged to consider whether the answer is reasonable, as this will help to detect these errors.

Question 2

(a) (i) 1. Most answers were correct and given with adequate explanation.

(a) (i) 2. Rather surprisingly, few candidates used the expression $\Delta Q = nc\Delta\theta$. The majority of correct answers were based on a two-step approach, calculating the energy for 0.19 mol to increase in temperature by 1 K and then using the given energy input.

(ii) Those candidates who obtained the correct result in **(i) part 2** usually succeeded in calculating the correct pressure. Where an incorrect value for the pressure was obtained, candidates often accepted their calculations without comment. In some scripts, candidates calculated the final temperature from the given pressure and then made some inappropriate calculation for the rise in temperature.

(b) There was considerable confusion of ideas when answering this part. Some suggested the temperature would rise because the gas had done work. In many answers, a link was attempted between ΔU, q and w but, frequently, the signs for these changes were not clear, leading to the conclusion that internal energy would increase.

Question 3

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

(ii) There were comparatively few fully correct answers because many candidates did not read the question carefully. Many did not include numerical values or did not give equations involving variation with respect to time. It was common to find that, in **part 1**, the displacement varied as sin 9.1*t*, rather than cos 9.1*t*.

(b) The majority of answers were correct but a significant number of candidates did not give the correct expression for the kinetic energy. Expressions such as $E_K = ½mr\omega^2$ and $E_K = ½mr^2\omega$ were common.

Question 4

(a)(i) Candidates should always use the symbols given in the question. Alternatives, unless fully explained, are not acceptable. In a minority of answers, the symbol *k* was used, without explaining that this is equal to $1/4\pi\varepsilon_0$.

(ii) Most candidates did give a correct algebraic formula for capacitance and then arrived at the correct expression. In many instances, explanation was incomplete or absent.

(b) (i) The majority were able to calculate the capacitance as being 5.0×10^{-11} F. Surprisingly, although knowing that 1 pF = 10^{-12} F, many failed to arrive at the correct answer.

(ii) A common error was to calculate the initial charge on the capacitor and then to consider this charge to be constant during the discharge. Quotation of the appropriate expression ($E = ½CV^2$) was common but there were then numerous arithmetical errors. Rather than calculate $(V_2^2 - V_1^2)$, many determined $(V_2 - V_1)^2$ or, less frequently, $(V_2 - V_1)$.

Question 5

(a) In general, definitions were not well expressed. Comparatively few even suggested that the tesla measures magnetic flux density. The statement frequently began with wording such as “A force of 1 N acting on a wire…” or “A conductor carrying a current of 1 A has a force…”.

(b) (i) With few exceptions, diagrams illustrated concentric circles with the correct direction. However, very few were drawn with sufficient care to show the relative separation of the lines.

(ii) Apart from power-of-ten errors, this calculation was completed successfully in most scripts.

(iii) Again, this was generally answered correctly. Some less able candidates did not realise that the force per unit length was required and, consequently, included the distance 4.5 cm in the calculation, despite this distance not being a length of any conductor.

(c) Answers to this question tended to be Centre-dependent. Some candidates based their argument on Newton’s third law. Others realised that the force per unit length depends on the product of the two currents. Both approaches were quite acceptable. Some candidates stated that the force would be different because the currents are different.

Question 6

(a) Answers were mostly satisfactory. A minority either did not include "rate of change" or considered induced current, rather than induced e.m.f. Candidates should be reminded that the law is stated by reference to proportionality.

(b) (i) A significant number of candidates either showed the point near to the input or wrote P in several incorrect positions.

(ii) Several different answers were given for this calculation. Many failed to include a $\sqrt{2}$ factor. Others inverted either the $\sqrt{2}$ factor or the turns ratio.

(c) (i) Frequently, the descriptions were vague, making reference to "smoothing the voltage". "Output voltage" was rarely included in an answer.

(ii) Candidates should realise that any line should show the main features. Often, rough sketches were draw with little similarity between two half cycles. Many drew lines that either started from below the peak or were convex upwards, rather than part of an exponential decrease.

Question 7

(a) There were very few convincing explanations. In many scripts, it was not made clear that each wavelength results from an electron changing energy levels. It was common to find that each wavelength was thought, quite wrongly, to be associated with a particular energy level.

(b) (i) There were many correct answers here but a significant number were spoiled by having arrows in the wrong direction or having double-headed arrows.

(ii) The correct expression was quoted in most scripts. A common error was a failure to convert the energy from units of eV to J.

(c) The three correct responses were in a minority. Many suggested two energies.

Question 8

(a) In many responses, either binding energy or mass defect were mentioned, without placing either in the context of an α-particle. Mass-energy was rarely discussed.

(b) (i) There were many correct answers. The most common error was to multiply each mass by the relevant mass number. Some candidates could not be given any credit because they quoted an incorrect answer without giving any form of derivation. Working should always be shown.

(ii) Most candidates did quote the correct expression. A significant number did not convert the mass in u to kg.

(iii) There were very few correct answers, possibly because most candidates did not appreciate the sign of the mass change in **(i)**. An alternative approach was to realise that the nucleus and the α-particle are both positively charged and would repel each other. Many did suggest that a minimum velocity is required for fusion to occur.

Section B

Question 9

In many answers to this question, there seemed to be a misunderstanding as to what was required. Some referred either to an insensitive voltmeter or based their answer on a warning so as not to run out of fuel.

(a) The given range was frequently inappropriate with values quoted where the line is curved (e.g. 20 litres).

(b) (i) Many candidates did not answer the question. Frequently, reference was made to a decreasing gradient without quoting data from the graph, as was required in the question. Very few gave a comparison of apparent fuel consumption for (e.g.) 70 litres to 80 litres with that for 40 litres to 50 litres.

(ii) Many candidates did comment that there would be fuel in the tank when the voltmeter reading is near to zero. Again, comments based on numerical evidence from the graph were rarely seen.

Question 10

(a) Most responses did refer to the product of density and speed. It was necessary to refer to the speed of ultrasound in the medium. A minority thought that the speed would be that of light.

(b) There were many vague statements based on the idea that it is useful to know about the difference between the acoustic impedances. Some did discuss how the magnitude of the difference affects the transmission and/or the reflection of the ultrasound. There some quotes of the intensity reflection coefficient, but these were frequently without explanation. The importance of the relative magnitudes of the difference and the sum of the impedances was not often considered.

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

Question 11

(a) Many answers dealt with anode voltage and hardness without any consideration of electron energy. There was widespread confusion between the beam of electrons and the X-ray beam. A significant number of answers linked anode voltage with the rate of production of electrons.

(b) (i) 1. The majority of answers were correct.

(i) 2. There were very few answers based on the notion that the intensity of a non-parallel beam changes, even when there is no absorption. The most common answer was based on the fact that either the expression for attenuation does not involve an angle or that the coefficient is referred to as a linear coefficient.

(b) (ii) There were many correct answers. Some candidates lost all credit as a result of making what was probably an arithmetical error but none of their working was shown.

Question 12

(a) There were some convincing answers but in many, the statements were limited to “something” being sent one after another. The bits in a word were rarely mentioned.

(b) Most answers were correct.

(c) Most candidates either determined the correct levels at the various times or drew a graph with an acceptable shape, regardless of the levels. Comparatively few were able to combine both of these elements to give the correct result.

(d) There were some excellent answers based on step height and step width. The majority referred to better quality of the waveform without giving detail as to why this would occur.

PHYSICS

Paper 9702/43

A2 Structured Questions

Key Messages

- Many candidates were better at performing mathematical calculations than constructing answers using sentences of continuous prose. It is important for candidates to practise answering questions that require them to write complete sentences, and ensure that these closely focus on the question being asked.
- A general weakness amongst candidates occurs where explanation of some aspect of physics is required. This weakness is also carried over to the explanation of calculations. Candidates would benefit greatly from practice at explaining their work so that it becomes natural to them to give fuller answers to questions, thus avoiding the unnecessary loss of credit.
- Candidates should be reminded that credit is not only awarded for final answers, but also for the approach to problems. Numerical working should therefore be accompanied by an adequate level of explanation. This explanation may gain some credit even if the numerical work is incorrect.

General Comments

Accurate recall of laws and definitions is fundamental to a good performance in the examination.

There was no real evidence amongst adequately prepared candidates of a shortage of time.

The candidates produced a wide range of responses and most questions provided good differentiation. The paper challenged the most able candidates, but was also accessible to those who were less able.

Comments on Specific Questions

Section A

Question 1

(a) It was generally understood that a gravitational field is a region of space where a mass experiences a force. A small minority of answers gave an inappropriate definition of gravitational field strength.

(b) (i) With few exceptions, a basic statement of Newton’s law of gravitation was given. Relatively few answers included the condition that the law applies to point masses.

(ii) Although most answers included the correct expression for gravitational field strength, two common errors were evident in the ensuing calculation of the ratio. These were calculating the inverse of the required ratio and not squaring the radii of the orbits.

(c) (i) The derivation of the expression for the mass of the Sun often consisted of pure algebraic working without any accompanying explanation. Those answers that did contain an explanation often stated that the gravitational force on the Earth is equal to the centripetal force, possibly implying that there is an equilibrium situation. It is more accurate and less ambiguous to explain that the gravitational force provides the centripetal force.

(ii) Although the calculation was a straightforward one, candidates needed to ensure that the radius of the Earth’s orbit was converted from units of km to m.

Question 2

(a) An ideal gas is one that obeys the equation $pV/T =$ constant for all values of pressure, volume and thermodynamic temperature. It was not sufficient to simply state one or two assumptions of the kinetic theory of gases.

(b) (i) The calculation caused few problems, although a small minority of answers contained a power-of-ten error in the value of the volume.

(ii) In order to determine the final temperature, it was necessary to apply the ideal gas equation to the total amount of gas. A common error was to apply the ideal gas equation to the gas in only one cylinder without realising that the amount of gas in that cylinder changes when the tap is opened.

(c) The majority of answers contained vague statements such as "work is done on the system". More precise wording was needed. When the tap is opened, gas passes from cylinder B to cylinder A. Work is done on the gas in cylinder A, causing an increase in internal energy and hence an increase in temperature.

Question 3

(a) The vast majority of answers to **(i)** and **(ii)** were fully correct.

(b) There were many incorrect graph shapes such as sinusoidal curves. The correct graph is a straight line with a negative gradient that passes through the origin. Candidates needed to ensure that they used reasonable scales and then accurately plotted the end points of the line.

(c) Different methods of calculation were possible. The simplest was to realise that the kinetic energy would be equal to the potential energy, thus enabling a general expression for potential energy to be equated to an expression for one half of the maximum kinetic energy. Candidates needed to adequately explain their chosen method of calculation.

Question 4

(a) This part of the question presented few problems for the well-prepared candidate. Reference must be made to a "unit positive charge" in the stated definition.

(b) Candidates should always explain any algebraic expressions that are used in a derivation. In this case they needed to explain that the kinetic energy of the charged particle is equal to its loss of potential energy.

(c) Most candidates used the expression given in **(b)** to calculate either the particle's speed or the electric potential of the sphere for the condition that the particle just reaches the surface of the sphere. They could then compare the calculated value of their chosen quantity with its actual value stated in the question. The most common approach was to calculate the particle's speed, although this was often wrongly interpreted as being its speed at the surface of the sphere.

Question 5

(a) Candidates need to be able to distinguish between the definition of a quantity and the definition of a unit. The tesla is a unit and so it should be defined in terms of the metre, the newton and the ampere. Candidates should also refer to force per unit length being one newton per metre, rather than a force of one newton on one metre length of wire.

(b) (i) Almost all answers were fully correct, although a small minority confused the permeability of free space with the permittivity of free space.

(ii) Some candidates were not able to distinguish between flux linkage and flux.

(c) (i) Faraday's law of electromagnetic induction was usually quoted correctly.

(ii) The most common error was to calculate an average e.m.f. that corresponded to the current in the solenoid being switched off, rather than being reversed.

Question 6

(a) (i) Candidates were expected to refer to the reduction of power loss in the core due to eddy currents. A common error was to believe that power loss and eddy currents are prevented rather than reduced.

(ii) An ideal transformer is one that has no power loss, so that the input power is equal to the output power.

(b) The calculation was usually done correctly, although a significant minority of candidates did not convert the root-mean-square voltage to a peak voltage.

Question 7

(a) (i) Many candidates stated that the threshold frequency is the minimum frequency for an electron to be emitted from the surface, without making it clear that it is the minimum frequency of electromagnetic radiation.

(ii) The vast majority of calculations were successful.

(b) A variety of approaches were possible. Some candidates calculated the frequency corresponding to a wavelength of 300 nm and compared this to the threshold frequencies of the metals. Others calculated the energy of a 300 nm photon and compared this to the work function energies of the metals. A small minority successfully calculated the threshold wavelengths of the metals and compared these to the wavelength of 300 nm.

(c) Although many candidates realised that a higher frequency would result in each photon having more energy, very few of these candidates went on to deduce that there must be fewer photons per unit time in order to maintain the same intensity. Thus, there is a decrease in the rate of emission of electrons. Most candidates had the false impression either that the rate of emission of electrons would stay the same because the light intensity is the same or that the rate of emission of electrons would increase because the electrons are emitted with more kinetic energy.

Question 8

(a) In nuclear fusion, two light nuclei combine to form a more massive nucleus. Candidates should use the correct terms in their statements. A nucleus should not be confused with an element, molecule, atom, nucleon or nuclide.

(b) (i) Most answers correctly calculated the change of mass in u and also stated the equation $E = mc^2$. However, the calculation of the released energy often contained arithmetic errors or omitted the conversion of the mass units from u to kg.

(ii) The reason for needing a high temperature was seldom understood. It is to ensure that the kinetic energies of the proton and the deuterium nucleus are large enough to enable them to overcome their mutual electrostatic repulsion.

Section B

Question 9

(a) Suitable sensing devices were usually suggested.

(b) (i) Most answers correctly stated that the resistance of the thermistor decreases and that V_{OUT} increases. However, very few answers explained why the decrease in thermistor resistance causes V_{OUT} to increase.

(ii) Although many candidates stated that the change in V_{OUT} varies non-linearly with the change in temperature, very few could give a reason for this. One reason is that the change in thermistor resistance varies non-linearly with the change in temperature. Another reason is that the change in V_{OUT} varies non-linearly with the change in thermistor resistance.

Question 10

(a) It was generally understood that sharpness relates to how well the edges of structures are defined. However, only a small minority of candidates appreciated that contrast relates to the difference in the degree of blackening between structures. Statements such as "contrast is the amount of blackening of the image" are incomplete and did not gain credit.

(b) Some candidates listed factors that merely affect sharpness rather than specifically cause a *loss* of sharpness. The most commonly stated correct causes were the scattering of photons in tissue, a large area anode and a large aperture through which the beam passes. A significant minority of candidates referred to causes of loss of contrast rather than loss of sharpness.

(c) (i) Most candidates could recall the appropriate equation, although power-of-ten errors were common and sometimes the inverse of the correct ratio was calculated.

(ii) The answer given here needed to be consistent with the value of the ratio calculated by the candidate in **(i)**. Explanations were often rather vague. A common misconception is that contrast is solely determined by the difference in the linear attenuation coefficients.

Question 11

(a) (i) A precisely worded statement was needed. The amplitude of the carrier wave varies in synchrony with the displacement of the information signal.

(ii) The most commonly-stated correct reasons for transmitting a modulated wave were that it would have less attenuation, a greater range and less interference from other radio waves. Another important advantage is that it will enable the use of a smaller aerial. Some candidates did not make it clear whether their comments referred to the modulated radio wave or the information signal radio wave.

(b) (i) There was considerable confusion here with many candidates basing their calculation on an incorrect carrier wave frequency of either 900 kHz or 909 Hz.

(ii) Most answers were correct.

(iii) There were few successful answers. The most common incorrect answers were 9 Hz and 918 kHz.

Question 12

A significant number of candidates had clearly practised this type of calculation and were able to obtain full marks. There were also many candidates who had difficulty in applying the appropriate equations. Common errors included having the power ratio the wrong way round, using logs to the base e and having power-of-ten errors in the substituted values of power. In **(b)**, a small minority of answers confused attenuation with gain so that the calculated attenuation had an inappropriate negative value. Some answers had an unreasonable order of magnitude. In such instances, candidates should be encouraged to re-check their calculations as they may be able to quickly identify an error in their working.

PHYSICS

Paper 9702/51

Planning, Analysis and Evaluation

Key Messages

- Candidates should be encouraged to read through the whole question paper before starting their answer.
- In **Question 1**, candidates must ensure that their answers are detailed and include explanations and answer the planning experiment set.
- 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

Question 2 was generally answered better than **Question 1** and a large number of candidates scored very highly. It was evident that Centres had spent time on the analysis section enabling their candidates to score all of the fifteen marks available. For **Question 1**, candidates should include greater detail in their answers. Candidates 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 or not reading off information from the graph correctly. A significant number of candidates did not realise that there was a false origin on the graph in **Question 2**. Candidates did not always indicate the methods used to determine either absolute or percentage uncertainties. Furthermore 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 website.

Comments on Specific Questions

Question 1

Candidates were required to design a laboratory experiment to investigate how the rate Q (volume per unit time) at which water flows varies with the vertical height h of the water and to determine a value for a constant η.

Candidates are advised to start **Question 1** by considering carefully the problem to be solved and in particular the variables that need to be kept constant for the experiment to be a fair test. The initial marks were awarded for correctly identifying the independent and dependent variables. Many candidates correctly stated that the vertical height h was the independent variable and the rate Q of the flow of water was the dependent variable. Some candidates suggested varying the length of the narrow tube which did not gain credit.

Marks are available for controlling variables, and candidates should indicate how a fair test could be made by keeping appropriate variables constant. As has been indicated in previous reports the word "controlled" is not an acceptable alternative to the word "constant". In this case marks were available for keeping the length of the narrow tube constant. There was also an additional detail mark for keeping the temperature of the water constant; credit was not given for just stating "keep the temperature constant".

Five marks are available for the methods of data collection. Candidates were expected to draw a labelled diagram of the arrangement of the apparatus. A number of candidates did not include any method of collecting the water; good candidates included a labelled measuring cylinder which gained this first mark. The second mark was awarded for the method of changing the vertical height h; many candidates did not state that they would move the (vertical) wide tube up or down.

To investigate the relationship and determine a value for η, most candidates realised that the vertical height and the length of the narrow tube needed to be measured and suggested using either a ruler or calipers. Candidates also realised that the diameter of the narrow tube needed to be measured; few realised it was the internal diameter that was needed and thus a micrometer was not considered a valid instrument. Good candidates suggested the use of vernier calipers or a travelling microscope. A large number of candidates described a clear method to determine the rate Q.

There are two marks available for the analysis of the data. It is expected that candidates would state the quantities that should be plotted on each axis of a graph for the first mark. The second mark was awarded for explaining how the gradient of the graph could be used to determine a value for η. To gain credit candidates needed to make η the subject of the expression which included the gradient (not Q/h). Some candidates suggested plotting log-log graphs. Again the relationship needed to be correctly interpreted for the award of the second mark. Additional detail marks were available for explaining that the relationship would be valid if a straight line passing through the origin was produced—this needed to be explicitly stated and credit was not given for a sketch graph. Some candidates did not state that the line had to be straight. Good candidates rearranged the given equation and described in detail what the gradient represented.

There was one mark available for describing an appropriate safety precaution. Candidates should be encouraged to ensure that safety precautions are relevant to the experiment and are clearly reasoned. In this case candidates were expected to describe a safety precaution relating to either methods to *prevent* spills (as opposed to solutions to dealing with spills) or methods to prevent injuries when adjusting the tubes. Vague answers such as "wear gloves in case the can is sharp" did not gain credit.

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. In addition to the points already mentioned above, credit was also given for repeating the experiment at each height and averaging the results, and for repeating the measurements of d at different angles across the end of the tube and averaging. Some candidates gained credit for a detailed explanation of how the density of the water was determined. Good candidates gave a method as to how the narrow tube was checked so that it was horizontal and gave additional detail of how to measure the height h to the centre of the narrow tube.

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 maximum voltage V across a capacitor varies with the value of its capacitance as another capacitor discharges through it.

(a) Candidates were asked to state the expressions that the gradient and y-intercept would represent if a graph of $1/V$ against C was plotted. This was generally well answered although weaker candidates appeared to be confused by the '1' in the original expression.

(b) Most candidates correctly included the column heading, although some candidates did not include a distinguishing mark between the quantity and unit. The calculated and recorded values of $1/V$ needed to be given to an appropriate number of significant figures. 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 *a* was given to two significant figures so it was expected that 1/*V* would be given to two or three significant figures.

(c) (i) Common mistakes included not plotting the points correctly—candidates should check suspect plots. Candidates should also be advised to ensure that the size of the plots is small; large 'blobs' are not accepted. 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) Most candidates attempted to draw the line of best fit. Candidates should 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. Some candidates were careless in their drawing of the lines; candidates should be encouraged to use a clear 30 cm ruler. 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 although candidates could often make their working clearer. Some candidates did not use a sensibly-sized triangle for their gradient calculation. A large number of good 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. $C / 10^{-3}$ F; this was not penalised at this stage. To determine the absolute error in the gradient, candidates were expected to find the difference between the gradient of the line of best fit and the gradient of the worst acceptable line. Again good 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) Candidates should have determined a value for the *y*-intercept. Many candidates did not realise that there was a false origin. Good candidates substituted a value from their line into $y = mx + c$. To determine the absolute 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 $y = mx + c$.

(d) (i) Candidates needed to determine a value for *E* using the value of the *y*-intercept; candidates who substituted values from the table of results did not gain credit. A number of candidates omitted the unit.

(ii) Candidates' values of *W* needed to be given in a specific range and their answers had to be to an appropriate number of significant figures with the correct unit. Again candidates needed to use their gradient value and the value for *E*. Common errors were to omit the unit or ignore the power of ten from the graph. Substituting data values from the table of results did not gain credit.

(iii) Many candidates correctly added the percentage uncertainty in the gradient to either the percentage uncertainty in *E* or the percentage uncertainty in the *y*-intercept. Other candidates either correctly determined the maximum value of *W* using the maximum value of *E* and the maximum value of gradient or the minimum value of *W* using the minimum value of *E* and the minimum value of gradient. Some candidates wrote down the fractional uncertainties and then incorrectly subtracted the fractional uncertainty in the gradient from the fractional uncertainty in *E*. Candidates should be encouraged to show their working for this mark.

It is essential that candidates clearly show their working, particularly to questions such as **(d)(i)** and **(d)(iii)**. Candidates should also be clear as to their understanding of percentage uncertainty and absolute uncertainty.

PHYSICS

Paper 9702/52

Planning, Analysis and Evaluation

Key Messages

- Candidates should be encouraged to read through the whole question paper before starting their answer.

- In **Question 1**, candidates must ensure that their answers are detailed and include explanations and answer the planning experiment set.

- 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

Question 2 was generally answered better than **Question 1** and a large number of candidates scored very highly. It was evident that Centres had spent time on the analysis section enabling their candidates to score all of the fifteen marks available. For **Question 1**, candidates should include greater detail in their answers. Candidates 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 or not reading off information from the graph correctly. Candidates did not always indicate the methods used to determine either absolute or percentage uncertainties. Furthermore 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 website.

Comments on Specific Questions

Question 1

Candidates were required to design a laboratory experiment to investigate how the peak alternating current varies with frequency in a circuit containing a coil of wire and to determine a value for a constant *L*.

Candidates are advised to start **Question 1** by considering carefully the problem to be solved and in particular the variables that need to be kept constant for the experiment to be a fair test. The initial marks were awarded for correctly identifying the independent and dependent variables. Many candidates correctly realised that the frequency of the alternating supply was the independent variable and the peak alternating current was the dependent variable. Some candidates suggested varying peak alternating current (by using resistors of different resistances) and then measuring the frequency which did not gain credit.

Marks are available for controlling variables, and candidates should indicate how a fair test could be made by keeping appropriate variables constant. As has been indicated in previous reports the word "controlled" is not an acceptable alternative to the word "constant". In this case marks were available for keeping the peak alternating voltage constant and an additional detail mark was available for keeping the resistance of the coil constant. Some candidates suggested keeping the resistance of the wires constant which was not credited. Credit was not given for keeping the number of turns constant in this case. Some candidates incorrectly suggested that the *L* in the equation of the question paper referred to the length of the coil.

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 clearly labelled using conventional symbols. The diagrams often showed misconceptions with many cathode-ray oscilloscopes placed in series with the coil and the power supply. The second mark was awarded to candidates who used a signal generator to vary the frequency. A common misconception was that the cathode-ray oscilloscope would vary the frequency. Other candidates suggested moving a bar magnet through a coil to generate the alternating current.

To investigate the relationship and determine a value for *L*, candidates needed to indicate how both the peak alternating current and the peak alternating voltage could be determined. Many candidates suggested the use of ammeters and voltmeters although the positioning of the meters in the circuit was often incorrect. Other candidates suggested the use of a cathode-ray oscilloscope. Many candidates suggested the use of the cathode-ray oscilloscope to determine the frequency.

Within the methods of data collection, candidates should also include additional detail. In this particular experiment, candidates could have explained how the reading from an ammeter or voltmeter could be converted to a peak value. When using the oscilloscope, marks were available for describing how the peak voltage or current could be determined in terms of the *y*-gain and height of the trace. Marks were also available for describing how the period and hence the frequency could be determined with the cathode ray oscilloscope. Some candidates suggested the use of a video camera to record the oscillations of a needle on the ammeter to determine frequency.

There are two marks available for the analysis of the data. It is expected that candidates would state the quantities that should be plotted on each axis of a graph for the first mark. A common error was for candidates to suggest plotting $1/I_0$ against *f*. The second mark was awarded for explaining how the gradient of the graph could be used to determine a value for *L*. To gain credit, candidates needed to make *L* the subject of the expression. Some candidates incorrectly suggested plotting log-log graphs.

Additional detail marks were available for explaining that the relationship would be valid if a straight line *not* passing through the origin was produced – this needed to be explicitly stated and credit was not given for a sketch graph. Some candidates did not state that the line had to be straight. Good candidates rearranged the given equation and described in detail what the gradient and *y*-intercept represented.

There was one mark available for the describing an appropriate safety precaution. Candidates should be encouraged to ensure that safety precautions are relevant to the experiment and are clearly reasoned – in this case candidates were expected to describe a safety precaution relating to the hot coil. Vague answers such as the heating of resistance wires or the danger of electrocution did not gain credit.

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. In addition to the points already mentioned above, credit was also given for using low frequencies to give large values of the peak alternating current.

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 horizontal distance *a* travelled by a deflected electron beam in an electric field is affected by the accelerating voltage *V*.

(a) Candidates were asked to state the expression that the gradient would represent if a graph of a^2 against *V* was plotted. This was generally well answered although a small number of candidates were confused by the square root sign.

(b) Most candidates correctly included the column heading, although some candidates did not include a distinguishing mark between the quantity and unit. The calculated and recorded values of a^2 needed to be given to an appropriate number of significant figures. 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 *a* was given to two significant figures so it was expected that a^2 would be given to two or three significant figures. The absolute uncertainties in a^2 were usually calculated correctly. The Examiners allow a number of different methods to determine the absolute uncertainties and do not penalise significant figures at this stage.

(c) (i) The graph plotting was quite variable. Common mistakes included not plotting the points correctly—candidates should check suspect plots. Candidates should also be advised to ensure that the size of the plots is small; large 'blobs' are not accepted. 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) Most candidates attempted to draw the line of best fit. Candidates should 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. Some candidates were careless in their drawing of the lines; candidates should be encouraged to use a clear 30 cm ruler. 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 although candidates could often make their working clearer. Some candidates did not use a sensibly-sized triangle for their gradient calculation. A large number of good 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. $a^2 / 10^{-4}\ \mathrm{m}^2$; this was not penalised at this stage. To determine the absolute error in the gradient, candidates were expected to find the difference between the gradient of the line of best fit and the gradient of the worst acceptable line. Again good 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.

(d) (i) Candidates needed to determine a value for *E* using the value of the gradient; candidates who substituted values from the table of results did not gain credit. Most mistakes were caused by the error reading off values from the *x*-axis which resulted in candidates gaining an answer with an incorrect power of ten. A number of candidates omitted the unit. Large numbers of candidates determined the unit from their working and wrote it as $\mathrm{m}^{-1}\ \mathrm{V}$.

(ii) Many candidates added the percentage uncertainty in the gradient to the percentage uncertainty in *b*. Other candidates either correctly determined the maximum value of *E* using the maximum value of *b* and the minimum value of gradient, or the minimum value of *E* using the minimum value of *b* and the maximum value of gradient. Some candidates wrote down the fractional uncertainties and then incorrectly subtracted the fractional uncertainty in the gradient from the fractional uncertainty in *b*. Candidates should be encouraged to show their working for this mark.

(e) Candidates needed to determine a value for *V* with its absolute uncertainty. Candidates' values of *V* needed to be given in a specific range and their answer had to be to an appropriate number of significant figures. There were many methods allowed to determine the absolute uncertainty in this value of *V*; candidates must show clearly their working. A number of the methods are to be found in the Mark Scheme. Some candidates correctly worked out the fractional uncertainty but then did not determine the absolute uncertainty.

It is essential that candidates clearly show their working, particularly to questions such as **(d)(ii)** and **(e)**. Candidates should also be clear as to their understanding of percentage uncertainty and absolute uncertainty.

PHYSICS

Paper 9702/53

Planning, Analysis and Evaluation

Key Messages

- Candidates should be encouraged to read through the whole question paper before starting their answer.
- In **Question 1**, candidates must ensure that their answers are detailed and include explanations and answer the planning experiment set.
- 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

Question 2 was generally answered better than **Question 1** and a large number of candidates scored very highly. It was evident that Centres had spent time on the analysis section enabling their candidates to score all of the fifteen marks available. For **Question 1**, candidates should include greater detail in their answers. Candidates 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 or not reading off information from the graph correctly. A significant number of candidates did not realise that there was a false origin on the graph in **Question 2**. Candidates did not always indicate the methods used to determine either absolute or percentage uncertainties. Furthermore 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 website.

Comments on Specific Questions

Question 1

Candidates were required to design a laboratory experiment to investigate how the rate Q (volume per unit time) at which water flows varies with the vertical height h of the water and to determine a value for a constant η.

Candidates are advised to start **Question 1** by considering carefully the problem to be solved and in particular the variables that need to be kept constant for the experiment to be a fair test. The initial marks were awarded for correctly identifying the independent and dependent variables. Many candidates correctly stated that the vertical height h was the independent variable and the rate Q of the flow of water was the dependent variable. Some candidates suggested varying the length of the narrow tube which did not gain credit.

Marks are available for controlling variables, and candidates should indicate how a fair test could be made by keeping appropriate variables constant. As has been indicated in previous reports the word "controlled" is not an acceptable alternative to the word "constant". In this case marks were available for keeping the length of the narrow tube constant. There was also an additional detail mark for keeping the temperature of the water constant; credit was not given for just stating "keep the temperature constant".

Five marks are available for the methods of data collection. Candidates were expected to draw a labelled diagram of the arrangement of the apparatus. A number of candidates did not include any method of collecting the water; good candidates included a labelled measuring cylinder which gained this first mark. The second mark was awarded for the method of changing the vertical height h; many candidates did not state that they would move the (vertical) wide tube up or down.

To investigate the relationship and determine a value for η, most candidates realised that the vertical height and the length of the narrow tube needed to be measured and suggested using either a ruler or calipers. Candidates also realised that the diameter of the narrow tube needed to be measured; few realised it was the internal diameter that was needed and thus a micrometer was not considered a valid instrument. Good candidates suggested the use of vernier calipers or a travelling microscope. A large number of candidates described a clear method to determine the rate Q.

There are two marks available for the analysis of the data. It is expected that candidates would state the quantities that should be plotted on each axis of a graph for the first mark. The second mark was awarded for explaining how the gradient of the graph could be used to determine a value for η. To gain credit candidates needed to make η the subject of the expression which included the gradient (not Q/h). Some candidates suggested plotting log-log graphs. Again the relationship needed to be correctly interpreted for the award of the second mark. Additional detail marks were available for explaining that the relationship would be valid if a straight line passing through the origin was produced—this needed to be explicitly stated and credit was not given for a sketch graph. Some candidates did not state that the line had to be straight. Good candidates rearranged the given equation and described in detail what the gradient represented.

There was one mark available for describing an appropriate safety precaution. Candidates should be encouraged to ensure that safety precautions are relevant to the experiment and are clearly reasoned. In this case candidates were expected to describe a safety precaution relating to either methods to *prevent* spills (as opposed to solutions to dealing with spills) or methods to prevent injuries when adjusting the tubes. Vague answers such as "wear gloves in case the can is sharp" did not gain credit.

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. In addition to the points already mentioned above, credit was also given for repeating the experiment at each height and averaging the results, and for repeating the measurements of d at different angles across the end of the tube and averaging. Some candidates gained credit for a detailed explanation of how the density of the water was determined. Good candidates gave a method as to how the narrow tube was checked so that it was horizontal and gave additional detail of how to measure the height h to the centre of the narrow tube.

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 maximum voltage V across a capacitor varies with the value of its capacitance as another capacitor discharges through it.

(a) Candidates were asked to state the expressions that the gradient and y-intercept would represent if a graph of $1/V$ against C was plotted. This was generally well answered although weaker candidates appeared to be confused by the '1' in the original expression.

(b) Most candidates correctly included the column heading, although some candidates did not include a distinguishing mark between the quantity and unit. The calculated and recorded values of $1/V$ needed to be given to an appropriate number of significant figures. 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 *a* was given to two significant figures so it was expected that 1/*V* would be given to two or three significant figures.

(c) (i) Common mistakes included not plotting the points correctly—candidates should check suspect plots. Candidates should also be advised to ensure that the size of the plots is small; large 'blobs' are not accepted. 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) Most candidates attempted to draw the line of best fit. Candidates should 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. Some candidates were careless in their drawing of the lines; candidates should be encouraged to use a clear 30 cm ruler. 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 although candidates could often make their working clearer. Some candidates did not use a sensibly-sized triangle for their gradient calculation. A large number of good 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. $C / 10^{-3}$ F; this was not penalised at this stage. To determine the absolute error in the gradient, candidates were expected to find the difference between the gradient of the line of best fit and the gradient of the worst acceptable line. Again good 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) Candidates should have determined a value for the *y*-intercept. Many candidates did not realise that there was a false origin. Good candidates substituted a value from their line into $y = mx + c$. To determine the absolute 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 $y = mx + c$.

(d) (i) Candidates needed to determine a value for *E* using the value of the *y*-intercept; candidates who substituted values from the table of results did not gain credit. A number of candidates omitted the unit.

(ii) Candidates' values of *W* needed to be given in a specific range and their answers had to be to an appropriate number of significant figures with the correct unit. Again candidates needed to use their gradient value and the value for *E*. Common errors were to omit the unit or ignore the power of ten from the graph. Substituting data values from the table of results did not gain credit.

(iii) Many candidates correctly added the percentage uncertainty in the gradient to either the percentage uncertainty in *E* or the percentage uncertainty in the *y*-intercept. Other candidates either correctly determined the maximum value of *W* using the maximum value of *E* and the maximum value of gradient or the minimum value of *W* using the minimum value of *E* and the minimum value of gradient. Some candidates wrote down the fractional uncertainties and then incorrectly subtracted the fractional uncertainty in the gradient from the fractional uncertainty in *E*. Candidates should be encouraged to show their working for this mark.

It is essential that candidates clearly show their working, particularly to questions such as **(d)(i)** and **(d)(iii)**. Candidates should also be clear as to their understanding of percentage uncertainty and absolute uncertainty.