PHYSICS

Paper 9702/11
Multiple Choice

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

General comments

There were some straightforward questions that were answered correctly by most candidates. Other questions were more demanding, with a significant proportion of candidates not giving the correct response. This spread of difficulty of the questions was intentional so that the paper, as a whole, differentiated as well as possible between candidates of different abilities.

Candidates should be advised to concentrate on the AS part of the syllabus when preparing for this paper. Furthermore, they should be aware that, on average, each question should be completed in 90 seconds. They should ensure that the available time is spread out over the whole paper.

Space is provided on the question paper for rough working. Candidates should not rely solely on mental agility when answering questions. Having decided on one of the possible answers, candidates should be encouraged to ask themselves whether the answer is reasonable so that they avoid trivial errors such as powers-of-ten.

Comments on specific questions

Questions 7, 20, 26, 28 and **33** were answered correctly by the great majority of candidates.

Question 4

This question was answered correctly by the more able candidates. Lower-scoring candidates tended to opt for either **A** or **C**.

Question 5

The very popular incorrect response was **D**. Candidates should realise that any uncertainty should be expressed to one significant figure.

Question 8

Although more able candidates did give the correct response, a large proportion of lower-scoring candidates assumed that the feather would fall with constant speed, despite being in a vacuum.

Question 10

Nearly all candidates opted for either **B** or **D**. Option **D** was favoured by higher-scoring candidates. The syllabus specifies that force is defined as the rate of change of momentum.

Question 12

This proved to be a difficult question with answers almost equally spread amongst the options. Clearly, candidates were not familiar with this type of question.

Question 13

This was answered correctly by higher-scoring candidates, but options **A** and **D** were popular alternatives.

Question 15

This question proved to be difficult for lower-scoring candidates with the three incorrect responses being chosen by approximately equal numbers of candidates.

Question 18

The most popular answer was **A**, thus suggesting confusion between energy and power.

Question 23

This question indicated a lack of understanding of the Young modulus. By far the most popular answer was option **D** with the correct response, **C**, being the least popular answer. The spring constant depends on the Young modulus, cross-sectional area and original length of a wire.

Question 24

This item discriminated well, with higher-scoring candidates answering correctly. Other candidates were equally divided amongst the incorrect options.

Question 31

Although this question was answered correctly by higher-scoring candidates, many others gave **C** as their choice.

Question 34

The use of ratios would appear to be a problem for many lower-scoring candidates.

Question 35

This item proved to be difficult but the more able candidates were successful. Option **D** was as popular an answer as the correct response.

Question 36

The most common answer was **D**. The correct response, **B**, was given by the higher-scoring candidates but otherwise, there appeared to be much guesswork.

Question 37

Potential divider questions do seem to cause difficulties for lower-scoring candidates. Popular incorrect responses were **B** and **C**.

PHYSICS

Paper 9702/12
Multiple Choice

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

General comments

There were some straightforward questions that were answered correctly by most candidates. Other questions were more demanding, with a significant proportion of candidates not giving the correct response. This spread of difficulty of the questions was intentional so that the paper, as a whole, differentiated as well as possible between candidates of different abilities.

Candidates should be advised to concentrate on the AS part of the syllabus when preparing for this paper. Furthermore, they should be aware that, on average, each question should be completed in 90 seconds. They should ensure that the available time is spread out over the whole paper.

Space is provided on the question paper for rough working. Candidates should not rely solely on mental agility when answering questions. Having decided on one of the possible answers, candidates should be encouraged to ask themselves whether the answer is reasonable so that they avoid trivial errors such as powers-of-ten.

Comments on specific questions

Questions 3, **11**, **19**, **27**, **39** and **40** were answered correctly by the great majority of candidates.

Question 4

This question was answered correctly by the more able candidates. Lower-scoring candidates tended to opt for option **A**.

Question 5

The very popular incorrect response was **D**. Many candidates are confused as to the difference between accuracy and precision.

Question 8

Although more able candidates did give the correct response, a large proportion of lower-scoring candidates opted for **C**. Candidates frequently equate, quite incorrectly, $(y - x)^2$ to $(y^2 - x^2)$.

Question 9

The correct response, **A**, was favoured by higher-scoring candidates. A popular misconception that the brick would fall with constant speed was indicated by the choice of **B**.

Question 12

Answers were almost equally divided between option **A** and the correct answer **D**. The relative speed of approach should be equal to the relative speed of separation in an elastic collision. The interpretation of the directions appeared to cause problems.

Question 13

This was answered correctly by higher-scoring candidates, but option **B** was very popular with lower-scoring candidates. This type of question appeared to be unfamiliar to many.

Question 14

This question proved to be difficult with all the options being almost equally popular, indicating much guess-work.

Question 15

A significant number of candidates appeared not to read the question carefully. They gave the torque produced by the cube and not the torque to maintain equilibrium.

Question 26

As is often the case in such questions, many weaker candidates did not allow for the reflection of the wave thus giving the answer as option **C**.

Question 30

The most common answer was option **D** but closely followed by the correct response, option **B**. There appeared to be confusion as to the relationship between wavelength and internodal distance.

Question 33

A minority of candidates gave the correct response. The most common answer was option **C** with a significant number of more able candidates opting for **B**. Clearly, this topic is not well understood.

Question 37

The only option where the lamps are lit dimly is the correct answer **D**. Many lower-scoring candidates opted for **C** where the lamps, although connected in series, are said to be lit normally.

PHYSICS

Paper 9702/13
Multiple Choice

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

General comments

There were some straightforward questions that were answered correctly by most candidates. Other questions were more demanding, with a significant proportion of candidates not giving the correct response. This spread of difficulty of the questions was intentional so that the paper, as a whole, differentiated as well as possible between candidates of different abilities.

Candidates should be advised to concentrate on the AS part of the syllabus when preparing for this paper. Furthermore, they should be aware that, on average, each question should be completed in 90 seconds. They should ensure that the available time is spread out over the whole paper.

Space is provided on the question paper for rough working. Candidates should not rely solely on mental agility when answering questions. Having decided on one of the possible answers, candidates should be encouraged to ask themselves whether the answer is reasonable so that they avoid trivial errors such as powers-of-ten.

Comments on specific questions

Questions 1, 6, 17, 25, 26, 27, 29 and **34** were answered correctly by the great majority of candidates.

Question 4

The very popular incorrect response was **D**. Candidates should realise that any uncertainty should be expressed to one significant figure.

Question 5

This question was answered correctly by the more able candidates. Lower-scoring candidates tended to opt for **A**.

Question 9

Although more able candidates did give the correct response, a large proportion of lower-scoring candidates seemed undecided between the three incorrect responses.

Question 10

This proved to be a difficult question with the majority of candidates opting for the incorrect response **C**. Clearly, candidates were not familiar with this type of question.

Question 12

The higher-scoring candidates chose the correct response. The majority of lower-scoring candidates opted for **D**.

Question 13

This question proved to be difficult for lower-scoring candidates with the three incorrect responses being chosen by approximately equal numbers of candidates.

Question 14

This was answered correctly by higher-scoring candidates, but option **D** was a popular alternative.

Question 19

The most popular answer was the correct response **B**, but nearly as many chose option **A**, thus indicating confusion between energy and power.

Question 21

This item discriminated well, with higher-scoring candidates answering correctly. Other candidates were divided amongst the incorrect options with **D** being the most popular incorrect response.

Question 22

This question indicated a lack of understanding of the Young modulus. By far the most popular answer was **D**. The spring constant depends on the Young modulus, cross-sectional area and original length of a wire.

Question 28

Although the correct option, **C**, was favoured by higher-scoring candidates, many others elected for **D**, thus assuming the angle for the first order to be 70°.

Question 31

Although this question was answered correctly by higher-scoring candidates, many others gave **C** as their choice.

Question 35

The correct response, **B**, was given by the higher-scoring candidates but otherwise, there appeared to be much guesswork.

Question 36

This item proved to be difficult but the more able candidates were successful. With lower-scoring candidates, there appeared to be a large element of guesswork.

PHYSICS

Paper 9702/21
AS Structured Questions

Key messages

- Candidates should be encouraged to show all their working in numerical questions. The full equation should be shown with the substitution of the data before any calculations are made. Candidates who show clear presentation of their working tend to receive more credit and make fewer mistakes.

- There was evidence of incorrect rounding in some of the answers to numerical questions. Candidates should be encouraged to read values carefully from their calculators before giving answers to two or three significant figures.

- Candidates were asked to use their knowledge and understanding to explain particular phenomena, often in unfamiliar situations. The candidates' descriptions were often lacked the required detail. Candidates should be encouraged to practise writing several sentences of continuous prose to give explanations of different phenomena in physics. Many examples of such exercises are to be found in past examination papers.

- Candidates should be advised to use the data given on page 2 of the question paper. In particular, the use of the approximation $g = 10\,\mathrm{m\,s^{-2}}$ should be discouraged.

General comments

Fundamental to a good performance in any examination is a sound knowledge of facts. However, some candidates appeared to be somewhat lacking in their knowledge and understanding of various aspects of the syllabus. Accurate recall of expressions is required but this was not evident in the work of weaker candidates.

Where calculations are required, work should be set out clearly. Candidates need to be reminded that credit is awarded not only for answers, but also for the approach to problems. Some candidates did not give even a basic explanation of the method being used, but simply substituted numbers into unexplained formulae with unfamiliar symbols. If the resulting answer was incorrect, no credit could be awarded.

Comments on specific questions

Question 1

The majority of candidates found this question a straightforward start to the examination.

(a) (i) This was answered correctly by almost all candidates.

(ii) The majority of answers were expressed clearly. Credit was lost where candidates changed the power of units by crossing out or altering what they had written, making their final answer illegible.

(b) Candidates should be advised to give the base units of each quantity in the form of an equation without any change of power. Only then should simplification take place, but on a different line of working. The usual errors were associated with either missing out the factor of r^4 or failing to give the power of four.

Question 2

(a) (i) The majority of candidates answered this correctly. Very few candidates attempted the calculation using the assumption that $g = 10\,\text{m}\,\text{s}^{-2}$, which would not have provided the value given in the question.

(ii) Again, the great majority of answers were correct. Almost all included the initial velocity of the ball.

(b) (i) Only a minority of answers included an initial statement making reference to rate of change of momentum, and references to change of any quantity were rarely seen. Consequently, the majority included only the rebound velocity. Candidates who did appreciate that there should be a change, frequently found the difference between the magnitudes of the velocities, rather than the sum. Answers stating that the force would be downwards were in the minority.

(ii) This was generally answered well, with only a minority using an incorrect value of speed when calculating the kinetic energy.

(c) As the speeds before and after impact were given, candidates should have been able to deduce that the impact would be inelastic. A significant number thought that the collision would be elastic because the ball reached the same height as given in **(a)(ii)**.

Question 3

(a) Most candidates gave a general statement regarding forces in equilibrium. Very few then went on to refer to the forces acting on the mass. Candidates should be able to distinguish between tension in the spring and the force on the mass due to the spring.

(b) There were a few candidates who gave correct answers for all three parts. However, many answers indicated a lack of understanding when trying to interpret the graph. A common error was to give the time for maximum speed as 0.40 s.

(c) (i) There were many appropriate statements of Hooke's law, although few correctly related the law to the graph in Fig. 3.4. A common misunderstanding was to state that mass is proportional to length, thus satisfying the law.

(ii) In most cases, the gradient of the graph was used with few attempting a 'one point' solution. A significant number of candidates took the value of g to be $10\,\text{m}\,\text{s}^{-2}$ and then made no comment as to why they had not obtained the value given for the force constant. Candidates should be advised always to use the data provided in the question paper.

(iii) The majority of candidates gave a correct expression for stored energy ($\frac{1}{2}kx^2$ or $\frac{1}{2}Fx$), but many then assumed that x was the length of the spring rather than its extension.

Question 4

This was generally answered well.

(a) (i) Most answers were correct. A significant number of candidates, calculated the current and then used the expression $V = IR$, rather than calculating the resistance directly using the expression $P = V^2/R$.

(ii) Again, the majority of answers were correct with very few errors being made when re-arranging the expression for resistivity.

(b) (i) Almost all candidates calculated this correctly. Candidates should always consider the number of significant figures when giving their answers.

(ii) Most answers did include a statement to the effect that the resistance must be reduced, but only the more able candidates gave a quantitative explanation.

Question 5

Many candidates found this question to be very demanding, and appeared not to have studied potential differences along a uniform wire.

(a) (i) Frequently, the definition was given without reference to the sums of the e.m.f. or the potential differences.

(ii) Many gave incorrect responses to this. Common answers were current, charge, p.d. and e.m.f.

(b) (i) There were relatively few correct answers. In the majority of cases, the total resistance of the circuit CXYDC was not considered.

(ii) An 'error-carried-forward' from **(i)** was accepted here, but this did not result in many candidates being given credit. Most answers involved the total resistance of the wire XY, rather than the resistance of the length XJ.

(iii) Very few candidates appreciated that the e.m.f. would be equal to the answer given in **(ii)**. In many scripts, this part of the question was not attempted.

(iv) The most common answer was based on negligible internal resistance. Very few understood that the current in the internal resistor would be zero and consequently there would be no 'lost volts'.

Question 6

(a) (i) There were many references to 'constant frequency' and 'constant wavelength'. Of the minority who did specify 'constant phase difference', few made any comment as to what would have this constant relationship.

(ii) A small minority of candidates referred to the condition based on path difference or on phase difference. However, the majority described this in very elementary terms based on 'crests' and 'troughs'.

(iii) Again, this was very poorly answered using elementary terms.

(iv) The majority of candidates answered this correctly. A minority made either power-of-ten errors or errors when manipulating the formula that gave rise to unrealistic answers.

(b) A significant minority linked changes in amplitude with changes in either frequency or wavelength. A number of candidates made reference to 'the fringes', without specifying whether the light fringes or the dark fringes were under consideration.

Question 7

(a) (i) X was frequently identified as being an α-particle, without any reference given to either the number of protons or the number of neutrons.

(ii) Where full credit was not awarded in this section, it was, in general, as a result of insufficient detail, for example 'positively charged', 'large mass', or 'low penetrating power'.

(b) This part was not understood by many candidates. Very few mentioned mass-energy conservation. Common answers were based on the idea of 'energy being conserved and thus energy being released as heat'. It was expected that candidates would appreciate that the mass difference would be seen as kinetic energy of products and/or energy of emitted photons.

PHYSICS

Paper 9702/22
AS Structured Questions

Key Messages

- Candidates should be encouraged to show all their working in numerical questions. The full equation should be shown with the substitution of the data before any calculations are made. Candidates who show clear presentation of their working tend to receive more credit and make fewer mistakes.

- There was evidence of incorrect rounding in some of the answers to numerical questions. Candidates should be encouraged to read values carefully from their calculators before giving answers to two or three significant figures.

- Candidates were asked to use their knowledge and understanding to explain particular phenomena, often in unfamiliar situations. The candidates' descriptions were often lacked the required detail. Candidates should be encouraged to practise writing several sentences of continuous prose to give explanations of different phenomena in physics. Many examples of such exercises are to be found in past examination papers.

- Candidates should be advised to use the data given on page 2 of the question paper. In particular, the use of the approximation $g = 10\,\mathrm{m\,s^{-2}}$ should be discouraged.

General comments

Candidates were in general able to score credit for numerical questions, but found descriptive questions more difficult. They should be encouraged to practise answering descriptive questions that require two or three sentences of explanation, many examples of which are available on past examination papers.

Comments on specific questions

Question 1

Candidates who presented their work clearly often obtained the correct answers and full credit. Calculation errors often occurred as a result of poor presentation of working.

(a) The majority of candidates made errors in the calculation. The main errors were to omit one or all of the required powers-of-ten from three of the substitutions made from Fig. 1.1 or to omit the power of four for the radius. Some made a rounding error in the answer for *C*, giving 1.03×10^{-3} instead of 1.04×10^{-3}.

(b) A significant number of candidates included the fractional or percentage uncertainties for the four terms involved. Errors were made by not adding all four percentage uncertainties, or by including the power-of-ten in the denominator (the quantity), but not in the numerator (the actual uncertainty). The factor of four in the fractional uncertainty for the radius was included by a large number of candidates. A significant minority gave the percentage uncertainty as their final answer. These candidates did not apply their answer to **(a)** to obtain the uncertainty in *C*.

(c) The answer was often given incorrectly with more than one significant figure for the uncertainty or the powers-of-ten included in one term but not the other.

Question 2

Candidates tended to gain more credit when their working was clear and logically presented.

(a)(i) This was generally well answered. The majority of candidates included the initial velocity in their calculation.

(ii) This was generally well answered.

(b) The graph was drawn incorrectly by the majority of candidates. The initial velocity was often shown to be zero and the velocity on rebound was seldom shown to be negative. The final stage from the ground to point B was often drawn with a line that had a gradient that was different from that in the initial stage.

(c) (i) **1.** The majority of candidates calculated the change in kinetic energy using the initial velocity and the rebound velocity, rather than the velocity at B which was zero. Some candidates calculated the change in kinetic energy using ½ $m(v_2 - v_1)^2$ instead of ½ $m(v_2^2 - v_1^2)$.

2. Well prepared candidates calculated the rebound height and the change in the potential energy. A significant number of candidates calculated the potential energy at one particular height and not the change in potential energy.

(ii) A very small number of candidates gave a numerical answer for the total change in the energy. The majority of answers were not acceptable at this level. The energy changes should have been linked to a particular system or body rather than lost as heat or sound.

Question 3

(a) The law was generally stated in an unacceptable form at this level. Very few stated 'constant velocity' and 'zero resultant force'.

(b) (i) A small minority of candidates were able to link the constant velocity of the log with a zero resultant force and hence equilibrium. A significant number suggested the log was not in equilibrium as it was moving with constant velocity.

(ii) A significant number of candidates calculated the component of the weight of the log acting down the slope. Many candidates then equated their value to the tension in the wire without any reference to the frictional force, or subtracted the frictional force from their value. Despite having used $9.81\,\mathrm{m\,s^{-2}}$ in **Question 2(a)**, a significant number of candidates used $g = 10\,\mathrm{m\,s^{-2}}$ in this part.

(iii) Well prepared candidates were able to explain the difference between the power produced by the motor and the gain in potential energy per second by describing the work done against the frictional force. Answers that merely stated that energy is lost to friction or heat were not given credit. Some candidates, ignoring the effects of the frictional force, suggested that the two were equal as the kinetic energy was constant.

Question 4

Candidates generally scored good marks for parts **(a)** and **(b)**.

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

(b) This part was generally well answered. A minority of candidates were unable to calculate the total resistance in the parallel section of the circuit, or made an error in the power-of-ten for the resistance value.

(c)(i) A large number of candidates did not make their explanations clear. There were many vague statements about resistance decreasing, without making a clear reference to the resistance of the LDR or the resistance of the complete circuit. A significant number of candidates incorrectly stated that the resistance of the LDR would increase with increased light intensity.

(ii) Well prepared candidates were able to explain that the resistance in the parallel section would decrease. Very few candidates were able to explain why this would cause the proportion of the p.d. available from the power supply to be less than in **(a)**.

Question 5

A large number of candidates answered this question well.

(a) The majority of candidates gave correct definitions here.

(b) (i) A significant number of candidates gave both required quantities. Candidates should be encouraged to give full descriptions of quantities to be measured. In this case the quantities required the ‘original’ length and the ‘cross-sectional’ area.

(ii) This was generally well answered. Some credit was lost by candidates who suggested that a micrometer screw gauge could be used to measure the radius or cross-sectional area of the wire. Some answers described the use of a ruler for the original length but this was considered to be too vague.

(iii) Many candidates answered this well. Errors were made by not converting the extension, from the reading on the graph, from millimetres to metres. A minority of candidates used the expression for work done as the product of force and extension rather than the product of the average force and extension.

(c) A large number of candidates did not recognise that a wire of the same dimensions but with a lower Young modulus value would extend more easily than the steel wire, and hence less force would be needed to produce the same extension. A small number of candidates disadvantaged themselves by drawing their own diagram, rather than drawing their answer on Fig. 5.1 as instructed in the question.

Question 6

The majority of candidates found this question demanding. The experimental description in **(b)** was omitted or poorly attempted by a significant number of candidates.

(a) The explanation of the formation of a stationary wave was not given in sufficient detail by the majority of candidates. Many suggested that the waves needed to superpose or interfere instead of meet or overlap. The principle of superposition was generally given correctly, but some candidates gave an incomplete statement, or added amplitudes rather than displacements for which no credit could be awarded.

(b) This part was generally poorly answered. The apparatus was often incomplete and not clearly labelled. A loudspeaker should have included a signal generator to produce a sound of variable frequency. Many omitted the adjustments to obtain resonance, and the distance between adjacent nodes or antinodes was often not linked with the wavelength.

(c) (i) Only a small number of candidates were able to correctly interpret the graph. A significant number of candidates appeared not to have read the text or Fig. 6.1 carefully and assumed that the graph was of displacement against distance rather than intensity against distance.

(ii) The distance between two adjacent nodes or two adjacent antinodes was linked to half the wavelength by only a small number of candidates.

Question 7

A significant number of candidates scored full credit in **(a)** but very few were able to give good answers in part **(b)**.

(a) The majority of candidates were able to obtain some credit. A significant number were unable to give the correct values for the neutron and so lost credit here.

(b) The link with the conservation of mass-energy was described by only a very small number of candidates.

PHYSICS

Paper 9702/23

AS Structured Questions

Key Messages

- Candidates should be encouraged to show all their working in numerical questions. The full equation should be shown with the substitution of the data before any calculations are made. Candidates who show clear presentation of their working tend to receive more credit and make fewer mistakes.

- There was evidence of incorrect rounding in some of the answers to numerical questions. Candidates should be encouraged to read values carefully from their calculators before giving answers to two or three significant figures.

- Candidates were asked to use their knowledge and understanding to explain particular phenomena, often in unfamiliar situations. The candidates' descriptions were often lacked the required detail. Candidates should be encouraged to practise writing several sentences of continuous prose to give explanations of different phenomena in physics. Many examples of such exercises are to be found in past examination papers.

- Candidates should be advised to use the data given on page 2 of the question paper. In particular, the use of the approximation $g = 10\,\mathrm{m\,s^{-2}}$ should be discouraged.

General comments

The well prepared candidates found many parts of questions to be straightforward. The basis of a good performance is good knowledge of definitions, laws and facts. A number of candidates did not demonstrate accurate recall of the basics.

Where a statement and an explanation are required, candidates should be encouraged to apply their knowledge and understanding to the situation. A relevant comment should be given in order to give a complete answer.

Poor presentation of calculations often caused candidates to make errors and not obtain the correct answer. Candidates should be encouraged to show all working in their calculations clearly, as credit may be awarded for a clear method in such circumstances.

Comments on specific questions

Question 1

This question was well answered by the well prepared candidates.

(a) The majority of candidates correctly distinguished between distance and displacement by indicating that one is a scalar and the other a vector. The explanation of displacement involving the distance of the straight line between two points was given by a small minority of candidates.

(b) Many statements lacked the required precision. References to constant motion rather than constant velocity, or no external force instead of zero resultant force, were not allowed at this level.

(c) (i) Candidates often gave Newton's first law as their explanation and did not refer to the forces acting on the tanker. Very few candidates described the need for a force in the opposite direction to that of the resultant force produced by the two tugs in order to produce the condition of equilibrium.

(ii) There were some very good scale diagrams drawn. Candidates who used this method to determine the magnitude of the forces then generally obtained the correct values. A number of candidates, however, demonstrated poor physics, equating the resolved component for each of the two tugs in the direction XY with the given resultant force in the direction XY.

Question 2

The majority of well prepared candidates gave good answers to most parts of this question.

(a) Many candidates were able to show the value required for the component of the weight. The inappropriate practice of assuming $g = 10\,\mathrm{m\,s^{-2}}$ was avoided to a great extent as this did not give the value stated in the question.

(b) (i) The determination of the resultant force was poorly answered, with the majority of candidates only gaining credit for the statement $F = ma$. The calculations for the resultant force F presented by many candidates did not include the component of the weight calculated in **(a)** or the frictional force.

(ii) This was generally well answered. Candidates applied the equations of constant acceleration correctly.

(c) The majority of candidates were able to show on the graph the initial constant acceleration from zero velocity until the cable breaks. The two later stages should have shown the log slowing to zero velocity, and then accelerating in the opposite direction. The majority of candidates were unable to interpret and then draw these two stages correctly on the graph.

Question 3

(a) Most candidates correctly stated the definitions of pressure and density. Well prepared candidates were able to link these two definitions and obtain an expression for the pressure in terms of the depth h in a liquid. Only a small minority went on to explain that the density had to be constant for the relationship between pressure and depth to be proportional.

(b) A small number of candidates recognised that the density of air is less at the top of a mountain. Very few candidates recognised the connection between the density not being constant and the effect on the relationship given in **(a)**.

Question 4

This question was generally well answered.

(a) The definition was given correctly by a significant number of well prepared candidates.

(b) (i) A correct calculation was presented by the majority of candidates. There were only a small number who did not know the correct equation or made an error converting millimetres to metres.

(ii) The work done was correctly calculated by a significant number of candidates.

(iii) The gain in gravitational potential energy was correctly calculated by a significant number of candidates.

(iv) A large number of calculations equated the gain in potential energy to the gain in kinetic energy. A minority of candidates equated the work done by the electric field on the charge calculated in **(ii)** to the total gain in potential and kinetic energy.

(v) The velocity was calculated correctly by a significant number of candidates. Many gained credit as error carried forward was applied for the answer obtained in **(iv)**.

Question 5

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

(ii) A significant number of candidates gave current rather than charge as the answer here.

(b) (i) The majority of candidates were unable to correctly apply Kirchhoff's second law. The two values of the e.m.f. were often added, and not all the resistances in the circuit were included in the stated equation.

(ii) This was generally well answered. An error made by a number of candidates was to use V^2/R for the power produced, with the internal resistance of the generator used for *R.*

(iii) The majority of candidates quoted the correct expression, and well prepared candidates used the total resistance in the circuit. A significant number of candidates used only the sum of the internal resistances, or the value of *R* determined in **(b)(i)**.

(iv) Well prepared candidates used the values obtained in **(b)(ii)** and **(iii)** to correctly calculate the efficiency. A significant number of candidates were unable to substitute the relevant values for the power into an acceptable expression for efficiency.

Question 6

(a) The majority of candidates did not link their answers to the diffraction grating as required in the question.

(i) The correct description for diffraction at a slit was given by a significant number of candidates. In order to give full explanations candidates needed to describe the overall effect of diffraction at each of the grating elements.

(ii) A significant number were unable to give an acceptable answer for the waves that had been diffracted by the diffraction grating.

(iii) Answers were often spoilt by the omission of key words in the explanation of superposition.

(b) Well prepared candidates gave correct solutions to this. A significant number of candidates confused the number of lines per metre with the width of the grating element, or made an incorrect conversion from millimetres to metres.

(c) Good candidates were able to link the shorter wavelength of blue light compared to red light with an increased number of orders. A significant number of candidates were unable to give this link or gave the incorrect variation for the wavelength.

Question 7

(a) Many of the answers gave the penetration properties of α-, β- and γ-radiation. Very few candidates correctly answered the question by describing a procedure that could demonstrate that the source does not emit β-particles.

(b) The effect of a magnetic field on α-, β- and γ-radiation was described by a small number of candidates, but these descriptions seldom included a demonstration of how the deflections would be monitored.

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.

- It is important that candidates write down all the working in calculations. If this is omitted, it may not be possible to award credit for correct graph read-offs or to make allowance for errors carried forward into calculations.

- The uncertainty in many types of measurements can be reduced by repeating and averaging. Where candidates do this, it is important that they write down all their raw readings as well as the average; this gives a useful indication of the scatter involved.

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 difficulties 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 candidates 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 almost all attempted both questions. They demonstrated good skills in the generation and handling of data, but more thought could be given 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 a pendulum whose swing is interrupted depends on its length.

Successful collection of data

(a) (iii) Most candidates recorded a value of *x* within the allowed range. A few candidates did not take account of the units given on the answer line and hence could not be awarded credit.

(b) (ii) Many candidates correctly recorded the time taken for repeated oscillations. A few candidates omitted to divide the result by the number of swings, or gave the answer without a suitable unit.

(c) Almost all the candidates were able to set up the experiment without assistance, and collect six sets of values of *x* and *T* showing the correct trend (*T* decreasing as *x* decreases).

Range and distribution of marks

(c) Most candidates recorded a suitable range of values for *x*. A few candidates could have made better use of the available range of values, as a difference of at least 25 cm between the maximum and minimum values was required in order to gain credit.

Presentation of data and observations

Table

(c) Many candidates were awarded credit for using the correct column headings. Other candidates needed to include units of $m^{½}$ for the $\sqrt{x}$ column instead of m (or omitting the unit completely). The majority of candidates gave the raw values of *x* to the nearest mm; others needed to allow for the precision of the metre rule, recording answers to the nearest mm rather than the nearest cm. Many expressed the values of $\sqrt{x}$ to the same number of significant figures as, or one more than, the value of *x,* gaining credit. The majority of candidates calculated $\sqrt{x}$ correctly.

Graph

(d) (i) Candidates were required to plot a graph of *T* against $\sqrt{x}$. Some candidates gained credit for drawing appropriate axes, with labels and sensible scales. Others chose to start the scale for the *T* 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 should be advised to check 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 gained credit for plotting tabulated readings. The diameter of each plotted point should be no more than half a small square, and the points should be plotted to an accuracy of within half a small square.

(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 lines would have been a better fit if they had been rotated slightly or moved to the left or right to give a better balance of points. Others were drawn to pass through a few points that lie on a line and did not best represent all of the data. Also commonly seen were lines that passed through the first and last points, regardless of the distribution of the other points.

Analysis, conclusions and evaluation

Interpretation of graph

(d) (iii) Many candidates used a suitably large triangle to calculate the gradient and gained credit for the read-offs and substitution into $\Delta y/\Delta x$ to find the gradient. In order for credit to be awarded, the read-offs had to be within half a small square of the best-fit line drawn, the substitution into $\Delta y/\Delta x$ (not $\Delta x/\Delta y$) clearly shown and the triangle drawn to calculate 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. It was important that 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 determine the *y*-intercept. Others chose a point that was in the table, but did not lie on the line of best fit.

Drawing conclusions

(e) Most candidates earned credit for recognising that *P* was equal to the value of the gradient and *Q* was equal to the value of the intercept calculated in **(d)(iii)**. Others tried to calculate *P* and *Q* by first substituting values into the given equation and then solving simultaneous equations. No credit was given for this as the question specifically asked for the answers in **(d)(iii)** to be used to determine *P* and *Q*. Some candidates did not include units with their answers. These could be deduced from the units used in the graph scales or from the equation given in this part.

Question 2

In this question candidates were required to investigate how the force required to pull a block up an inclined plane depends on the angle between the inclined plane and the bench.

Successful collection of data

(a) (iii) Most candidates recorded a value of F_0 with a suitable unit, although some gave an answer in grams rather than newtons. Only a few candidates repeated their measurements to find an average value for F_0 which was required for full credit to be awarded.

(b) (ii) Most candidates gave a value of θ, with a unit. A few candidates misread the protractor and recorded an answer greater than 90°, or gave a raw value with an unjustifiable degree of precision, e.g. 26.3°.

(c) (ii) Almost all candidates recorded a value for *F*.

(d) Almost all candidates recorded a second value of θ, which was usually smaller than the first value, obtained in **(b)(ii)**.

Quality

(d) Almost all candidates found that the first value of *F* (for the steeper slope) was greater than the second value and were awarded credit.

Display of calculation and reasoning

(a) (v) Almost all candidates recorded the value of μ to 2 or 3 significant figures.

(b) (iii) Almost all candidates were able to calculate ($\sin\theta + \mu\cos\theta$) correctly.

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

Analysis, conclusions and evaluation

(e) (ii) Few candidates compared the percentage difference in their values of *k* by testing it against a specified percentage uncertainty, either taken from **(a)(iii)** or estimated. Answers such as 'the difference in the two *k* values is very large/quite small' were insufficient. Candidates were expected to calculate the percentage difference between the two *k* values, make a judgement as to whether this was above or below what was anticipated, and then state what they think is a sensible limit for the percentage uncertainty for this particular experiment.

Estimating uncertainties in F_0

(a) (iv) Most candidates were familiar with the equation for calculating percentage uncertainty, although few made a realistic estimate of the absolute uncertainty (0.4 – 1.0 N). Candidates should recall that the absolute uncertainty in the value of F_0 depends not only on the precision of the measuring instrument being used, but also on the nature of the experiment itself. Where measurements have been repeated, an acceptable method to estimate the absolute uncertainty is to calculate half the range of the results obtained earlier and use this as the absolute uncertainty.

Evaluation

(f) Many candidates were only able to score half the available credit 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 difficulty in judging the value of *F* because the block starts to move suddenly and without warning at which point the force changes. Answers such as 'it is difficult to measure the force when the block starts to move' were just re-stating the problem set, so were not credited.

Candidates are encouraged to suggest detailed practical solutions that either improve technique or give more reliable data. Answers can be improved by stating the methods used for each solution e.g. '…apply the force using a string passing over a pulley and loaded with hanging masses…' or '…video the newton-meter and then play back frame-by-frame to find the maximum force reached…'. In doing this candidates should look at how each solution helps this particular experiment. 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 creditworthy. A table giving details of limitations and potential improvements can be found in the mark scheme, together with some answers that did not receive credit.

PHYSICS

Paper 9702/32
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.

- It is important that candidates write down all the working in calculations. If this is omitted, it may not be possible to award credit for correct graph read-offs or to make allowance for errors carried forward into calculations.

- The uncertainty in many types of measurements can be reduced by repeating and averaging. Where candidates do this, it is important that they write down all their raw readings as well as the average; this gives a useful indication of the scatter involved.

General comments

Good answers in **Question 1** showed that candidates had taken care when measuring lengths to the nearest millimetre and were familiar with using equipment of this type. Candidates need to be aware that when they are provided with a metre rule marked in millimetres their readings should be recorded to this precision. Good answers showed scales that spread the plots over more than half the graph grid. Read-offs were clearly shown at the corners of a large enough triangle used to determine the gradient of a well drawn straight line. The link was made between gradient and intercept values and the constants in the equation.

In **Question 2** good answers showed that candidates had recorded diameter readings to the nearest 0.1 mm or better, depending on the measuring instrument used, and had taken care to record repeated newton-meter readings. Good answers showed clear thinking about why it was difficult to take measurements of diameter and force.

Comments on specific questions

Question 1

Candidates investigated how the equilibrium position of a suspended mass was linked to its height above the bench.

Successful collection of data

(a) The majority of Centres had carefully set up the stands, plumb-line and spring for the candidates. Where height above the bench was an issue, it would have been acceptable to support the stands on blocks. Good answers showed that candidates were able to measure length *L* and give a value that was in the required range. Candidates need to be aware of a unit provided on the answer line. Noting this should have avoided answers such as 65 m.

(b) Good answers showed that candidates were able to manipulate and measure the mass and crocodile clip, recording height h_0 to the nearest millimetre, e.g. 0.107 m. Other answers recorded the height to the nearest centimetre, e.g. 0.11 m, which should have been written as 0.110 m. Candidates who did not notice the m unit on the answer line gave answers such as 11 m.

Range and distribution of readings

(c) More able candidates noted the guidance in the question for the *d* range (5 cm to 30 cm), and used a wide range of distances *d* including one value of 10 cm or less and one value of 25 cm or more.

Good answers had points lying close to the drawn line, so the quality of the data, judged by the amount of scatter about a straight-line trend on the graph, was good, reflecting the good preparation Centres had given. Candidates need to appreciate that they have to be patient when taking readings.

Table of results

(c) The majority of candidates had been well prepared in how to present their raw readings clearly, in a well drawn table.

Good answers showed table headings which included suitable units, e.g. $\left(\frac{L}{2}-d\right)^2$ / m^2, $(h - h_o)$ / m.

It is important to separate the quantity from the unit using a forward slash. The headings in every column in the table must have a quantity and a unit, not just the quantity. Candidates need to be aware that the unit of the quantity $\left(\frac{L}{2}-d\right)^2$ is not m but m^2.

Candidates need to understand how the brackets affect the calculation they do, e.g. $\left(\frac{L}{2}-d\right)^2$ does not have the same value as $\left(\frac{L}{2}-d^2\right)$. Good answers gave the values of $\left(\frac{L}{2}-d\right)^2$ correctly, with an appropriate number of significant figures. Candidates should be reminded that the value from their calculation must not be presented as a fraction; calculated values show the number of significant figures used, so no credit can be given for correct significant figures if the answer is given as a fraction.

The calculated values are needed in the table so that plotted points can be checked.

In good answers the values of *h* and *d* were recorded to the nearest millimetre, e.g. 25.0 cm or 0.250 m. Candidates need to understand that, as their metre rule is marked in millimetres, it is appropriate to record their measurements to the nearest millimetre.

Graph

(d) The standard of graph work was usually high, again reflecting good preparation by Centres. Good answers showed candidates choosing to use scales based on, for example 2, 4, 5 or 10, and with plots spread over at least half the grid in each direction. Candidates should understand that if their plots only occupy a couple of large squares on their grid they need to choose a better scale. A scale where candidates make one large square worth for example 65 or 12.3, or awkward scales based on 3, 6, or using fractions rather than values, or a scale where one of the plots lies off the printed grid should not be used. It should be easy to read off intermediate points without having to use a calculator.

Stronger candidates were able to plot points accurately. Candidates should be reminded that plot points larger than half a small square in diameter are not acceptable and will not gain credit. Good answers used a sharp pencil so that the crosses used to mark plots and the drawn line were well under half a small square thick.

In good answers all results in the table were plotted; candidates should remember that omitting a point because it lies off the grid will lose credit. Candidates need to look critically at how they choose their scales to ensure all the points will fit on, remembering that the graph's origin (0,0) does not have to be included if this results in all the points occupying a small region of the grid.

Good answers showed an appropriate straight line with a good balance of plots along the whole line. The line of best fit should be drawn so that all the points have a fair balance along the whole line; practice in drawing this type of line is essential. 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 to draw the best line.

Interpretation of graph

(d) The candidates who gave the best responses had been well prepared on how to find gradient and intercept values of a straight line graph. For the gradient a large triangle should be chosen, and read-offs accurately taken from points which lie on the line. Good answers used these read-offs correctly, clearly showing the working, before writing the calculated value of the gradient on the answer line. The intercept was correctly calculated by substituting read-offs from a point 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 read directly from the graph.

When finding the gradient, two points should be chosen which lie on the line and are not close together. Ideally the length of the hypotenuse of the triangle should be greater than half the length of the drawn line. Candidates should also understand that choosing table values for the points of the triangle is unreliable as these may not lie on the drawn line. Candidates must remember that the gradient is $\Delta y / \Delta x$, not $\Delta x / \Delta y$.

In finding the *y*-intercept, candidates need to calculate the *y*-intercept rather than choosing to extend the line below the grid in an attempt to estimate a read-off, which is an inaccurate method.

Drawing conclusions

(e) Good answers showed a clear understanding of how the values found for gradient and intercept in part **(d)** related to constants *a* and *b* in the equation of part **(e)**. The exact values from **(d)(iii)** were used with no recalculation. Some candidates carried out further calculations, often using simultaneous equations, which were unnecessary.

The best answers included the correct units, e.g. for *a* the correct unit was m, or another unit of length, and for *b* the unit was m^2. Candidates should focus on understanding the units here and ensure that the unit they give is consistent with the value. Some candidates missed off the power of ten, giving an answer such as $1\,m^2$ instead of the correct value of $1 \times 10^{-3}\,m^2$. It is important to understand how to work out the units of the constants in an equation.

Question 2

In this question candidates were asked to investigate the adhesive strength of Blu-Tack by squashing some between rulers and measuring the force needed to detach the top ruler. The experiment demanded a gentle, continuous pulling force on the newton-meter, whilst viewing from perpendicularly above the pointer on the newton-meter scale. The best answers showed repeat readings from the newton-meter; there was adequate time allowed for candidates to take repeat readings and they should be encouraged to do so. The more able candidates gave answers that showed that while doing the experiment, they had thought about why it was difficult to take accurate readings. Thinking about difficulties during the experiment will make answering the final section in **(f)** much easier.

Successful collection and presentation of data

(a) (iii) The better candidates measured the diameter of the ball with the vernier caliper and recorded the diameter to the nearest 0.1 mm.

(b) (i) Good answers recorded *d* and gave the unit. Candidates need to be aware that when there is no unit on the answer line they are expected to state the unit for their measurement.

(iii) The area was correctly calculated by the better candidates and the correct unit of m^2, cm^2 or mm^2, whichever was consistent with their values, was given. Again, as no unit was provided on the answer line, candidates were required to give a correct, consistent unit.

(c) (ii) Better candidates carried out the procedure more than once and gave repeat values of *F* here and in **(d)(ii)** including the correct unit of N.

(d) (ii) Good answers showed that the candidates had repeated the experiment using a slightly smaller or larger piece of Blu-Tack. Candidates should read the question carefully and take note of help given in the question. Here, if the statement "You should be aware that a large change in diameter could result in a reading outside the range of the newton-meter" was observed, answers where readings were within the scale limits of the newton-meter were produced.

The better answers showed that a larger ball gave a larger force at detachment, whilst a smaller ball gave a smaller detachment force.

Estimating uncertainties

(b) (ii) Good answers correctly calculated the percentage uncertainty of the *d* value, clearly showing the method used. Candidates needed to appreciate that as the diameter was measured through the top ruler, and it was unlikely that the disc was perfectly circular, *d* could not be measured to the nearest millimetre, so the minimum estimate of the absolute uncertainty was 2 mm. Some good answers also featured repeat readings of *d*, and then used half the range to find the percentage uncertainty. Candidates must remember that it is half the range that can be used here and not the full range.

Display of calculation and reasoning

(e) (i) Clear working was shown in the good answers and two values were correctly calculated for the quantity *k* in the equation. Candidates must know how to rearrange the equation to find *k* rather than 1/*k*.

Analysis and conclusions

(e) (ii) The better candidates calculated the percentage difference between the two *k* values, stated the percentage value they would use as a criterion for comparison, and then used this criterion to decide whether or not the relationship was valid.

The stated criterion can be the percentage uncertainty found in **(b)(ii)**, or a percentage value that the candidate decides is appropriate for this experiment such as 10% or 20%.

Better candidates stated that if the percentage difference between the two *k* values was less than the criterion, the relationship was supported, and if the percentage difference was greater than the criterion, the relationship was not supported.

It is important to note that stating that the difference between the two *k* values is "small" or "large" is not sufficient, and that using rounding to make the *k* values equal is not good enough.

Some good candidates used equally valid methods of comparison, such as calculating error bands for the two *k* values and seeing whether the bands overlapped.

Evaluation

(f) Good answers suggested detailed, relevant limitations and improvements.

The best answers were characterised by detailed suggestions specific to this experiment with the Blu-Tack and newton-meter.

General vague ideas such as 'zero errors', 'systematic errors' or 'parallax errors' with no link to the experiment were not credited. In this experiment parallax errors related to the newton-meter were irrelevant. Good answers linked the parallax error idea to reading the diameter of the Blu-Tack through the ruler, as it was not possible to make contact with the Blu-Tack.

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". Simply stating "take more readings", which could have the meaning of more 'repeat' readings, or suggesting "taking the average" were not good responses.

Good answers stated that the newton-meter reading as the ruler detached was only shown for a very short time. The corresponding improvement in good answers suggested using a video to record the newton-meter readings and then to playback the video to note the reading at detachment. It is important that the difference in meaning between stating "the newton-meter reading will be videoed and played back" and stating "take a slow motion video" is noted; the video is not taken in slow motion, it is the replay which is done at a slow frame rate. Candidates needed to appreciate that as it was not important to know when the required newton-meter reading occurred, it was not necessary to link the video to time.

Candidates need to understand the need for detail. A statement "use a video" is not sufficient. "Use a video with playback" is also not sufficient as it does not identify what is being measured. Relevant detail is the key.

Suggesting an improvement such as "use a digital newton-meter" is not good enough. Good answers explained that a newton-meter which could record the value at detachment was required. A good answer stated "use a digital newton-meter connected to a data logger which records the force over time, then analyse the force trace to find the exact force at detachment."

Please refer to the published mark scheme for examples of other creditworthy responses.

PHYSICS

Paper 9702/33
Advanced Practical Skills 1

Key messages

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- It is important that candidates write down all the working in calculations. If this is omitted, it may not be possible to award credit for correct graph read-offs or to make allowance for errors carried forward into calculations.

- The uncertainty in many types of measurements can be reduced by repeating and averaging. Where candidates do this, it is important that they write down all their raw readings as well as the average; this gives a useful indication of the scatter involved.

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 investigate how the extension of an arrangement of springs depends on the loads applied to it.

Successful collection of data

(a) (ii) Most candidates measured the distance h_0 within the allowed range of 0.50 – 0.70 m. A few candidates needed to take account of the units given on the answer line in order to gain credit.

(b) (iii) Most candidates recorded the a value for *h* that was less than h_0. Some candidates omitted the unit.

(c) Most candidates were able to set up the experiment without assistance and collect five sets of values for *h* and *m.* Many candidates showed an incorrect trend (*h* increases as *m* increases) in the results, suggesting that either the wooden rod was not adjusted to the horizontal after adding new masses, or candidates added masses to the central mass hanger.

Range and distribution of marks

(c) Many candidates did not extend the range of values of *m* over at least 3.50 kg. Candidates could have made better use of the available range of masses provided.

Presentation of data and observations

Table

(c) Many candidates were able to include correct units with the column headings including /kg^{-1} and /m kg^{-1}. Some candidates omitted a unit or did not show a separating mark between the quantity and unit. Many candidates correctly stated the raw values of *h* 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. Some candidates were able to state the significant figures in the calculated quantity to the same or one more than the number used for the corresponding raw value of *m.* For a mass of 0.250 kg many candidates incorrectly recorded 4 kg^{-1} or 4.0 kg^{-1} instead of 4.00 kg^{-1}. Many candidates were able to calculate $\frac{(h_0 - h)}{m}$ correctly.

Graph

(d) (i) Candidates were required to plot a graph of $\frac{(h_0 - h)}{m}$ against $\frac{1}{m}$. Some candidates gained credit for drawing appropriate axes with labels and sensible scales. Others chose to start the scale for the *y*-axis at zero, leading to a compressed scale with all the points occupying less than half the graph grid in the *y*-direction. Some weak candidates left $\frac{1}{m}$ in a fraction form on the *x*-axis and tried to produce a graph scale on that basis. Candidates could 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 gained credit for plotting tabulated readings. The diameter of each plotted point should be no more than half a small square, and the points should be plotted to an accuracy of within half a small square.

(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 lines would have been a better fit if they had been rotated slightly or moved to the left or right to give a better balance of points. Others were drawn to pass through a few points that lie on a line and did not best represent all of the data. Also commonly seen were lines that passed through the first and last points, regardless of the distribution of the other points.

Analysis, conclusions and evaluation

Interpretation of graph

(d) (iii) Many candidates used a suitably large triangle to calculate the gradient and gained credit for the read-offs and substitution into $\Delta y/\Delta x$ to find the gradient. In order for credit to be awarded, the read-offs had to be within half a small square of the best-fit line drawn, the substitution into $\Delta y/\Delta x$ (not $\Delta x/\Delta y$) clearly shown and the triangle drawn to calculate the gradient 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. It was important that 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 determine the *y*-intercept. Others chose a point that was in the table, but did not lie on the line of best fit.

Drawing conclusions

(e) Most candidates earned credit for recognising that *P* was equal to the value of the gradient and *Q* was equal to the value of the intercept calculated in **(d)(iii)**. Others tried to calculate *P* and *Q* by first substituting values into the given equation and then solving simultaneous equations. No credit was given for this as the question specifically asked for the answers in **(d)(iii)** to be used to determine *P* and *Q*. Some candidates did not include units with their answers. These could be deduced from the units used in the graph scales or from the equation given in this part.

Question 2

In this question candidates were required to investigate how the cooling rate of a hot liquid depends on the surface area of the liquid exposed to air.

Successful collection of data

(b) (ii) Most candidates recorded a value of θ_0 to the nearest degree Celsius. A few candidates gave a raw value with an unjustifiable degree of precision e.g. 74.8 °C.

(iii) The majority of candidates recorded a value of θ, with a unit. A few candidates omitted C in the unit, or even the whole unit.

(c) (i) Most candidates recorded a value of *d* to the nearest mm with a consistent unit. A few candidates measured *d* to the nearest cm without taking advantage of the ruler being precise to the nearest mm. Some candidates repeated their measurement of *d* (to find an average value of *d*) either in this part or in **(d)** for further credit.

(d) Many candidates recorded values for θ_0 and θ for the bowl. Some candidates did not consider having the same starting temperature for the hot water in the bowl as that for the water in the cup (to within 1 °C).

Quality

(d) Most candidates found that the temperature drop for the vessel of smaller diameter (the cup) was less than the value for the larger vessel (the bowl) and were awarded credit.

Presentation of data and observations

Display of calculation and reasoning

(b) (iv) Most candidates were able to calculate $\Delta\theta$.

(e) (i) Many candidates were able to calculate *k* for the two sets of data. A few candidates forgot to square *d* or incorrectly rearranged the equation to find *k*.

(ii) Many candidates were able to relate the number of significant figures in *k* to *d* and $\Delta\theta$ gaining credit. Other candidates related to just one quantity, or to the calculated quantity d^2.

Analysis, conclusions and evaluation

(e) (iii) Few candidates compared the percentage difference in their values of *k* by testing it against a specified percentage uncertainty, either taken from **(c)(ii)** or estimated themselves. Answers such as 'the difference in the two *k* values is very large/quite small' were 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 in *d*

(c) (ii) Most candidates were familiar with the equation for calculating percentage uncertainty, although few made a realistic estimate of the absolute uncertainty (2 – 5 mm). Candidates should recall that the absolute uncertainty in the value of *d* depends not only on the precision of the measuring instrument being used, but also on the nature of the experiment itself. Where measurements have been repeated, an acceptable method to estimate the absolute uncertainty is to calculate half the range of the results obtained earlier and use this as the absolute uncertainty.

Evaluation

(f) Many candidates were only able to score half the available credit in this section. The key to this section is for candidates to identify genuine problems associated with setting up this experiment and obtaining readings, e.g. 'the difficulty in taking the value of *d* because the ruler was too long to get close to the diameter of the water surface' or 'the diameter at the water surface was different from that at the top of the cup'. An answer such as 'it is difficult to measure *d*' is insufficient to gain credit without an explanation.

Candidates are encouraged to suggest <u>detailed</u> practical solutions that either improve technique or give more reliable data. Answers can be improved by stating the methods used for each solution, e.g. 'lag the cup/bowl to prevent heat loss through the sides' or 'use vernier calipers to measure the inside diameter'. In doing this candidates should look at how each solution helps this particular experiment. 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 creditworthy. A table giving details of limitations and potential improvements can be found in the mark scheme, together with some answers that did not receive credit.

PHYSICS

Paper 9702/34
Advanced Practical Skills 2

Key messages

- The Supervisor's Report and the sample set of results provided by each Centre form an important part of the marking process, and candidates may be disadvantaged if either is missing. The Supervisor's Report should include details of any difficulties or apparatus changes during the examination so that allowance can be made when marking. If help is provided to candidates, the Supervisor's Report **MUST** include candidate numbers and details of the assistance given.
- 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.
- It is important that candidates write down all the working in calculations. If this is omitted, it may not be possible to award credit for correct graph read-offs or to make allowance for errors carried forward into calculations.
- The uncertainty in many types of measurements can be reduced by repeating and averaging. Where candidates do this, it is important that they write down all their raw readings as well as the average; this gives a useful indication of the scatter involved.

General comments

There were few problems with providing the necessary apparatus for **Question 1**, but some candidates' comments suggested that the diameter and depth of the holes drilled in the wooden block in **Question 2** were not as specified in the Confidential Instructions. Although the Examiners make every attempt to take this into account, Centres risk inadvertently disadvantaging their candidates if the apparatus is varied in this way.

Candidates had time to complete both questions and in most cases the instructions were understood and followed carefully. There was variation between Centres, but most candidates had been well prepared in the presentation of data in tables and graphs, leading to a generally good performance in **Question 1**. A number of candidates had difficulty using the micrometer screw gauge in **Question 2**, although the challenging discussion section at the end of the question was often well answered.

Comments on specific questions

Question 1

In this question candidates were required to investigate the behaviour of an electrical circuit. Many Centres had prepared candidates thoroughly in the skills tested, and there were many very good answers.

Successful collection of data

(a) There were many good answers with current values in the expected range and with the correct unit.

(b) Most candidates found that adding a parallel resistor increased the circuit current, as expected.

(c) Nearly all candidates recorded results for six different resistors with a trend showing I decreasing with increasing *R*. Candidates need to be aware that the absence of a clear trend could indicate that their circuit is incorrectly connected; a request for help could put this right and would only incur a small penalty.

Range and distribution of values

(c) Good answers used a suitably large part of this range by including values of *R* close to the maximum and the minimum available.

Table

(c) Tables were generally neat and clear. In good answers the headings included units, separated from their quantity by a forward slash, and all values of I were given to the same number of decimal places. Each of the resistors *R* was labelled with a value to two significant figures, and so the calculated value 1/*R* should have had two or three significant figures, e.g. an *R* value of 1.0 kΩ would give 1/*R* a value of 1.0 or 1.00 $k\Omega^{-1}$, not 1 $k\Omega^{-1}$.

Graph

(d) Good answers were characterised by neat graphs produced using a sharp pencil, to avoid thick lines and large, inaccurate plots; they used sensible scales (see Key Messages) and simple values for major divisions labels, e.g. 0.5, 1.0, 1.5, etc. rather than 0.58, 1.08, etc. Graphs with awkward scales led to a higher incidence of mis-plotting and mistaken read-offs.

This experiment produces a clear linear trend and a good answer included a line of best fit that passed through the points in the manner described in the syllabus. Candidates should understand that if they choose to ignore one outlying point they should label it as anomalous, even if only by circling it.

The quality of results achieved by many candidates, as indicated by scatter on the graph, was very good.

Interpretation of graph

(d) In good answers a large triangle was added to the graph to indicate the coordinates used to calculate the gradient. The *y*-intercept could be read directly from the graph if the *x*-axis started at zero, but even so most candidates chose to calculate it, usually successfully. Most Centres had prepared candidates well in the clear presentation of their working.

Drawing conclusions

(e) Good answers showed clearly that the value of the constant *b* had been found by dividing the graph gradient by the graph intercept; the question required this method to be used rather than calculating *b* using simultaneous equations.

In the best answers a value for *b* was found close to the theoretical 1 kΩ, and was recorded with its correct unit.

Question 2

In this question candidates were required to observe a pendulum collision with a copper wire specimen to investigate the energy needed to bend the wire.

The experiment required the use of a micrometer to measure the wire diameter, and many candidates had difficulty with this; some with reading the instrument and others with understanding the units involved.

Successful collection of data

(b) Good answers recorded repeated readings which gave an average diameter in the expected range; allowance was made if the Supervisor's Report indicated that an alternative wire had been substituted for the one specified.

Other answers used an incorrect unit power of 10, e.g. 0.092 mm instead of 0.92 mm, or, more commonly, misread the barrel divisions, e.g. recording 1.42 mm instead of 0.92 mm. These errors were penalised here but 'error carried forward' was applied in subsequent calculations.

(d), **(e)** In good answers candidates recorded and found the average of the maximum pointer readings from several tests for each wire diameter, with all values of θ greater than 90°.

Estimating uncertainties

(c) Most candidates knew the method for calculating percentage uncertainty and there were many good answers which showed the working clearly.

Display of calculation and reasoning

(c) Nearly every candidate correctly calculated the value for $\sin(180° - \theta)$ and recorded their value to an appropriate number of significant figures.

(f) (i) Calculation of the two values of *k* was well done by the majority of candidates.

Conclusions

(f) (ii) Most candidates knew that for the suggested relationship to be supported their two values of *k* had to be nearly the same, and in their answers they had to decide and state whether or not this was true. In good answers the two *k* values were compared in terms of their percentage difference, not just the difference between them, and this was compared with a stated tolerance that the candidate thought was appropriate in this experiment. For example 'the difference between *k* values is 7.2% and since this is less than 10% the evidence supports the suggested relationship'.

Some good candidates used equally valid methods of comparison, such as calculating error bands for the two *k* values and seeing whether the bands overlapped.

Evaluation

(g) This section was often well answered, with strong candidates scoring most of the available credit for clear descriptions of difficulties and improvements.

Good answers listed the difficulties encountered, linking each to the particular measurement affected, and went on to suggest changes in enough detail to enable the reader to carry them out, avoiding changes that could have been made by the candidate using the equipment available.

In this experiment most of the problems were associated with measuring the maximum pointer deflection θ, parallax error, a moving pointer, a thick pointer, and so on.

Good answers went on to suggest related improvements, e.g. reposition the pointer closer to the scale, video the motion and replay to view the angle, and also changes to make the apparatus easier to use such as to fix the pointer in a hole drilled in the pendulum, or to clamp the wooden block to the bench.

Other answers were too general or vague, e.g. 'zero error', 'systematic error', 'fix the pointer properly'.

The published mark scheme gives further detail of acceptable responses.

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.

- It is important that candidates write down all the working in calculations. If this is omitted, it may not be possible to award credit for correct graph read-offs or to make allowance for errors carried forward into calculations.

- The uncertainty in many types of measurements can be reduced by repeating and averaging. Where candidates do this, it is important that they write down all their raw readings as well as the average; this gives a useful indication of the scatter involved.

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 investigate how the current in a circuit depends on the resistance of the circuit.

Successful collection of data

(b) (ii) Some candidates recorded an ammeter reading in range, with a consistent unit, for n = 3. Other candidates did not recognise that a current of 8 A or 80 A, (instead of 80 mA), would be an unrealistic current. Other candidates connected any number of resistors other than n = 3.

(c) Many candidates were able to set up the experiment without assistance and collect five sets of values for I and n to give the correct trend.

Range and distribution of marks

(c) Many candidates did not extend the range over six or seven resistors. Most candidates chose to go from n = 1 to n = 6 to give a range of 5.

Presentation of data and observations

Table

(c) Many candidates were able to include correct column headings including $\frac{(n+1)}{I}$ / A^{-1}. Some candidates recorded the column heading $\frac{(n+1)}{I}$ but omitted the unit or the separating mark between the heading and unit. Many candidates correctly stated the raw values of I to the nearest 0.1 mA or better; other candidates added extra zeros onto the current readings. Some candidates were able to state the calculated quantity $\frac{(n+1)}{I}$ to the same number of significant figures as, or one more than, the number used for the corresponding raw value of I.

Graph

(d) (i) Candidates were required to plot a graph of $\frac{(n+1)}{I}$ / A^{-1} against n. Some candidates gained credit for drawing appropriate axes with labels and sensible scales. Candidates could 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 gained credit for plotting tabulated readings. The diameter of each plotted point should be no more than half a small square, and the points should be plotted to an accuracy of within half a small square.

(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 lines would have been a better fit if they had been rotated slightly or moved to the left or right to give a better balance of points. Others were drawn to pass through a few points that lie on a line and did not best represent all of the data. Also commonly seen were lines that passed through the first and last points, regardless of the distribution of the other points.

Analysis, conclusions and evaluation

Interpretation of graph

(d) (iii) Many candidates used a suitably large triangle to calculate the gradient and gained credit for the read-offs and substitution into $\Delta y/\Delta x$ to find the gradient. In order for credit to be awarded, the read-offs had to be within half a small square of the best-fit line drawn, the substitution into $\Delta y/\Delta x$ (not $\Delta x/\Delta y$) clearly shown and the triangle drawn to calculate 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. It was important that 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 determine the y-intercept. Others chose a point that was in the table, but did not lie on the line of best fit.

Drawing conclusions

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

(f) Many candidates were able to measure and record a value for the voltage *V* in the correct range.

(g) Some candidates used answers to **(e)** and **(f)** to calculate *R* with appropriate units. Many candidates gave answers with power-of-ten errors as a result of carrying forward the mA as A for the current units.

Question 2

In this question candidates were required to investigate how the rotational motion of an object depends on its mass.

Successful collection of data

(b) (ii) Most candidates recorded a value of *x* in range to the nearest mm. A few candidates gave raw values to the nearest cm without taking advantage of the ruler being precise to the nearest mm, or added zeros to give an unjustifiable degree of precision.

(c) (ii) Most candidates recorded a value for x_1 with a consistent unit. A few candidates omitted the unit.

(d) (ii) Most candidates recorded a value for x_2.

(e) (iii) Many candidates recorded a value for the time of oscillation of the 100 g mass within the required range. Many candidates gained further credit for repeating the procedure.

(f) Many candidates recorded a value for *T* using the disc.

Quality

(f) Most candidates found that the value of *T* for the 100 g mass was smaller than that for the disc and were awarded credit.

Presentation of data and observations

Display of calculation and reasoning

(c) (iii) Most candidates were able to calculate d_1.

(g) (i) Many candidates were able to calculate *k* for the two sets of data. Some candidates forgot to square *T* or incorrectly transferred the data for the disc into for the 100 g mass; others incorrectly rearranged the equation for *k.*

(ii) Many candidates were able to relate the number of significant figures in *k* to *d* and *T* gaining credit. Other candidates related to just one quantity or to the calculated quantity T^2.

Analysis, conclusions and evaluation

(g) (iii) Few candidates compared the percentage difference in their values of *k* by testing it against a specified percentage uncertainty, either taken from **(c)(iv)** 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 in *d*

(c) (iv) Most candidates were familiar with the equation for calculating percentage uncertainty, although few made a realistic estimate of the absolute uncertainty (2 – 5 mm). Candidates should recall that the absolute uncertainty in the value of d_1 depends not only on the precision of the measuring instrument being used, but also on the nature of the experiment itself. Where measurements have been repeated, an acceptable method to estimate the absolute uncertainty is to calculate half the range of the results obtained earlier and use this as the absolute uncertainty.

Evaluation

(f) Many candidates were only able to score half the available credit in this section. The key to this section is for candidates to identify genuine problems associated with setting up this experiment and obtaining readings, e.g. 'difficult to make plasticine into a circular disc' or 'difficult to determine the end of an oscillation' or 'difficult to measure *d* as cannot determine where the middle of the disc is'. An answer such as 'it is difficult to measure *d*' is insufficient to gain credit without an explanation.

Candidates are encouraged to suggest <u>detailed</u> practical solutions that either improve technique or give more reliable data. Answers can be improved by stating the methods used for each solution, e.g. 'use a mould to shape the plasticine' or 'use a fiducial marker'. In doing this candidates should look at how each solution helps this particular experiment. 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 creditworthy. A table giving details of limitations and potential improvements can be found in the mark scheme, together with some answers that did not receive credit.

PHYSICS

Paper 9702/41

A2 Structured Questions

Key Messages

- Candidates should be encouraged to practise writing several sentences of continuous prose to give explanations of different phenomena in physics. Many examples of such exercises are to be found in past examination papers.
- Candidates should be reminded to pay close attention to the prefixes of units in order to prevent power-of-ten errors occurring in calculations. A quick check on whether an answer is 'reasonable' would allow candidates to detect errors in their working.
- Most candidates could improve their performance by learning the precise details of definitions and laws required by the syllabus. Quantities are defined in terms of other quantities, and do not depend on units.

General Comments

The paper challenged the most able candidates, while still providing the weaker candidates with ample opportunities to score credit.

Although there were many good answers, there were comparatively few candidates whose performance over the entire paper was consistently good, with many performing slightly better on ***Section A*** than on ***Section B***. Most candidates would benefit from having a deeper understanding of the production and use of X-rays.

Candidates should be advised that credit is awarded not only for final answers, but also for the way in which problems are approached. It is essential that all working is clearly presented so that each step in a calculation is shown explicitly.

Comments on Specific Questions

Section A

Question 1

(a) There were many good answers. A common error was to refer to one kilogram instead of unit mass.

(b) Many candidates correctly explained that gravitational force is always attractive. However, few went on to explain that a body in the gravitational field will do work as it moves from infinity.

(c) There was more than one method of deriving the correct expression. Most candidates considered the work done to move the small mass by a short distance. In order to gain full credit, candidates needed to show each step in their derivation and fully explain any approximations that are used. Candidates also needed to explain any symbols that were not explained in the stem of the question.

(d) The calculation presented few problems for well-prepared candidates. However, a significant minority equated an expression for the gravitational force to an inappropriate expression of centripetal force. Others confused the planet's radius with its diameter.

Question 2

(a) (i) With few exceptions, a correct answer was given.

(ii) Candidates needed to make it clear that it is the total volume of all the molecules, rather than the volume of a single molecule, that is negligible compared to the volume of the containing vessel.

(b) Many candidates need to improve their understanding of the kinetic theory of gases. The velocity of a molecule was often confused with a component of its velocity. Few candidates distinguished between the square speed of a single molecule and the mean square speed of all the molecules.

(c) Although there were many successful calculations, others confused mean square speed with root mean square speed or omitted the conversion of temperature from degrees Celsius to kelvin.

Question 3

(a) A correct definition was usually given. The most common error was to define either specific latent heat of fusion or specific latent heat of vaporisation, rather than specific latent heat in general.

(b) Candidates calculated the final answer in one of two ways. The first way was to find the total loss in energy after two minutes and then convert this to a rate of energy loss. The second way was to find the power needed for evaporation and then subtract this from the power supplied by the kettle.

Question 4

(a) Most calculations were successful. A small minority confused the displacement of the ball with its amplitude of oscillation.

(b) There were few fully correct responses. The speed of the ball is a sine function. Squaring this sine function to obtain kinetic energy will result in a sinusoidally shaped wave of double the frequency.

Question 5

(a) The definition of electric field strength needed to be stated precisely. It is clearly defined in the syllabus as being the force per unit positive charge acting on a stationary point charge.

(b) (i) A high proportion of the candidates could recall the correct expression for the electric field strength, although the ensuing calculation often contained power-of-ten errors.

(ii) The vast majority of candidates correctly used the expression $V = \frac{Q}{4\pi\varepsilon_0 r}$. However, a small minority chose to use the expression $E = \frac{V}{r}$. In the general situation, field strength is not equal to the ratio of potential and radius, but rather $E = \Delta V/\Delta d$. It happens to be that for an isolated point charge the expression $E = \frac{V}{r}$ is valid, but any candidate wishing to use that expression must clearly explain the reason for its validity.

Question 6

(a) Parts **(i)** and **(ii)** were well answered. In part **(iii)**, a common error was to use a period of 10 ms.

(b) Parts **(i)** and **(ii)** were usually answered successfully. The calculation in part **(iii)** proved to be more problematic, with few candidates using the correct discharge time of 7 ms.

(c) Very few candidates realised that, for a single discharge, the average potential difference across the resistor is 3.2 V.

Question 7

(a) Most drawings showed the magnetic field lines as concentric circles in the correct direction. Candidates should be advised that a change in the spacing of the magnetic field lines indicates a change in the magnetic field strength. Most candidates needed to be more careful when drawing the increasing separation of the field lines as the distance from the wire increases.

(b) (i) The direction of the force on wire B was usually indicated correctly.

(ii) Only a small minority of answers correctly explained that the force on wire A is equal to the force on wire B, as outlined in Newton's third law. A few answers gave an alternative explanation that the force on each wire is dependent on the product of the two currents.

(c) Candidates are advised to note the credit allocation for each question part as this is a guide to the depth required for the answer. The majority of answers described only one aspect of the force. The most common response was to state that the force would always be attractive. It was seldom stated that the variation of the force would be sinusoidal at double the frequency of the current.

Question 8

(a) Most candidates could recall that a photon is a quantum of energy of electromagnetic radiation. Only a small minority explained that this energy is equal to the Planck constant multiplied by the frequency. A statement of the algebraic expression needed to be accompanied by an explanation of all symbols.

(b) When describing the process of photon emission, candidates must distinguish between energy levels and the change between energy levels. Many candidates incorrectly associate a photon of a specific wavelength to a specific energy level.

Question 9

(a) (i) The majority of candidates could correctly define the decay constant as being the probability of decay of a nucleus per unit time.

(ii) Candidates should be advised that it is essential that every step in a derivation is shown explicitly. Weaker candidates often presented intermediate expressions that did not distinguish between either N and N_0 or t and $t_{½}$.

(b) Most calculations were successful.

(c) The random nature of decay and the effect of background radiation were usually identified correctly. A significant number of answers incorrectly referred to the effect of environmental factors, such as temperature.

Section B

Question 10

(a) Almost without exception, the light-dependent resistor was identified correctly.

(b) The two resistors were frequently drawn in the correct configuration. However, the relay was usually connected wrongly and not represented by the correct symbol.

(c) (i) Candidates sometimes stated the purpose of a relay in general terms, rather than stating the purpose of the relay when used in the given circuit.

(ii) Only a small proportion of the candidates understood that the diode is connected in the direction shown to ensure that the relay switches on the lamp only when the output of the operational amplifier becomes negative.

Question 11

(a) (i) Answers needed to include a clear statement that X-ray photons are produced when the electrons are decelerated. Very few answers explained that the X-rays present a continuous distribution of wavelengths because the electrons undergo a range of decelerations at the anode.

(ii) Many candidates were unable to explain that the sharp cut-off at short wavelength corresponds to an electron 'losing' all of its energy in one collision to produce a single photon. Less able candidates sometimes gave irrelevant explanations of either the characteristic X-ray spectrum or the threshold wavelength in the photoelectric effect.

(b) It was generally appreciated that *hardness* is a measure of the penetration of the beam and that the hardness is controlled by changing the accelerating voltage. However, despite the credit allocation for this part of the question, there were few answers that went on to explain that increased hardness is associated with increased penetration and increased accelerating voltage. A common error was to confuse the hardness of an X-ray beam with its intensity.

(c) (i) The majority of candidates realised that long-wavelength X-ray radiation is more likely to be absorbed in the body. However, a common misconception was that the longer wavelength X-ray photons posed a greater health hazard because they had greater energy.

(ii) A high proportion of the candidates knew that the hazard would be minimised by the use of an aluminium filter in the X-ray beam. However, there were also inappropriate references to the use of a grid.

Question 12

(a) Most candidates did refer to a strong uniform magnetic field and a calibrated non-uniform magnetic field. However, the purpose of these two fields was not always made clear.

(b) There were many well-explained solutions to both parts **(i)** and **(ii)**.

Question 13

(a) (i) Although the majority of candidates understood that neighbouring cells use different carrier frequencies in order to avoid interference, few realised that this interference would occur near to cell boundaries.

(ii) It was seldom appreciated that in order for the cells to have a larger area, it is necessary to increase the signal strength and that this might be hazardous to health. Some candidates thought, incorrectly, that the cell size was determined solely by the 'line of sight' of the signals so that the cell area would extend all the way to the horizon.

(b) The majority of candidates realised that the mobile phone handset continues to send out an identifying signal. Thus, the computer at the cellular exchange continually selects the base station with the strongest signal and allocates a carrier frequency. Poor answers often confused the roles of the different parts of the mobile phone system.

PHYSICS

Paper 9702/42
AS Structured Questions

Key messages

- Candidates should be encouraged to practise writing several sentences of continuous prose to give explanations of different phenomena in physics. Many examples of such exercises are to be found in past examination papers.
- Candidates should be reminded to pay close attention to the prefixes of units in order to prevent power-of-ten errors occurring in calculations. A quick check on whether an answer is 'reasonable' would allow candidates to detect errors in their working.
- Most candidates could improve their performance by learning the precise details of definitions and laws required by the syllabus. Quantities are defined in terms of other quantities, and do not depend on units.

General comments

There seemed to be ample time for well-prepared candidates to complete their answers. As is usually the case, a large proportion of candidates performed better in ***Section A*** than in ***Section B***.

Candidates should be advised that credit is awarded not only for final answers, but also for the way in which problems are approached. It is essential that all working is clearly presented so that each step in a calculation is shown explicitly.

Comments on specific questions

Section A

Question 1

(a) Candidates should be encouraged to be precise when stating laws and defining quantities. Although nearly all answers did have the basis of the law, some lost credit through failing to refer to the *product* of the masses or to *point* masses.

(b) (i) In general, full substitution for the time period was shown.

(ii) Most candidates did follow the instruction to derive the given value for the mass. Consequently, they derived an expression, in terms of r and ω, for this mass. Power-of-ten errors were not uncommon. Candidates should be aware that astronomical distances are frequently given in km, whereas the formulae are appropriate to distances in metres.

(c) (i) This was generally well done, although a minority of candidates failed to square the distance despite showing r^2 in the formula.

(ii) This derivation caused considerable difficulty for many candidates. It was usual to find that the expression $\frac{GMm}{r}$ for potential energy was quoted. The subsequent calculation was then not completed with sufficient accuracy, thus giving an answer of zero. Those who used the expression $F\Delta x$ seldom explained that the force could be considered as being constant because x is very much smaller than the distance r.

Question 2

(a) Candidates who knew the relevant expressions usually gave well-presented answers.

(b) There were several different approaches to this calculation. Many spotted that one half of the total energy (given) could be equated to the potential energy and thus x could be determined. Others made the calculation more difficult by using expressions that involved both x and x_0.

(c) (i) This was expected to be a straightforward start to the graphical work but many drew the line from –3.0 cm to +3.0 cm.

(ii) Most sketches indicated an acceptable curve for the kinetic energy. The intercepts were frequently indicated with insufficient care.

(iii) Usually, this curve was shown as the inverse of the kinetic energy curve. Very few showed the curves crossing at the appropriate points, even when these points had been calculated correctly in **(b)**.

(d) There were many different answers, apart from gravitational potential energy. Some quoted strain energy and there were a number of other suggestions, some of which were not even forms of energy, such as friction and weight.

Question 3

(a) In most answers, kinetic energy and potential energy were mentioned. The fact that the energies are associated with molecules, rather than 'the system', and that the kinetic energy is associated with random motion needed to be included.

(b) For credit to be awarded, changes, if any, to both kinetic energy and potential energy had to be identified. In **(i)**, it was common to find that kinetic energy was not mentioned and potential energy was associated with an increase in the separation of molecules. Answers in **(ii)** were much more comprehensive, with many candidates discussing kinetic, potential and internal energy. Candidates should be advised that it is insufficient to discuss a *change*. The direction of any such change should be identified.

Question 4

This proved to be the lowest scoring question on the paper.

(a) (i) There was widespread misunderstanding of the negative axis for U_P. In general it was thought that U_P increased as r decreased. Where the correct relationship between U_P and r was stated, very few linked this to an attractive force between the mass and the proton.

(ii) Only a few satisfactory answers were given. Candidates were unable to link either electric potential energy to the product of charge and potential or electric field strength to potential gradient. Most stated, without any justification, that the gradient is equal to force.

(b) The majority of candidates attempted to answer this by drawing the gradient at the relevant point. There were many errors associated with powers-of-ten as a result of failing to read the graph axes carefully.

Question 5

(a) Very few candidates gave a complete definition. Frequently, the fact that the conductor must be straight was omitted. Candidates should refer to force per unit length being one newton per metre, rather than a force of one newton on a one metre length of wire.

(b) (i) There were some good comprehensive answers. Some candidates identified the increased reading with a downward force on the wire, or attempted an explanation by referring to the left-hand rule.

(ii) Most candidates were familiar with this type of calculation but there were numerous errors with powers-of-ten. Candidates should be advised to use the data given on the question paper. The use of $g = 10\,\text{m s}^{-2}$ in calculations where data is given to two significant figures is unacceptable, especially when the final answer is then quoted to three or more significant figures.

(c) Although there were some good answers here, many were incomplete. It was common to find that the new maximum current was calculated but this was not related to force. Many others calculated the new maximum force without commenting on the variation.

Question 6

(a) This was very poorly answered by all but a very small minority. A description of the apparatus was minimal with few describing parallel or horizontal metal plates. Where marks were scored, it was for an adjustment of the potential difference to make the oil drop stationary. Where an expression for this stationary situation was given, then the means by which the mass was found was omitted.

(b) There were very few correct answers seen for this part. Many candidates merely quoted the value for the charge on the electron. Few appeared to appreciate how the data should be interpreted.

Question 7

(a) A significant number of answers either did not include a reference to *minimum* energy or described the energy as being required for photoelectric emission. The terms *photon* and *electron* were confused by some candidates.

(b) There were many good answers here. Almost all successfully converted eV to J. It was pleasing to note that few candidates switched their answers to meet the value given in the Data.

(c) In general, the line was drawn with sufficient precision to be awarded full credit. Almost all drew lines that were parallel to the given line.

Question 8

(a) Most candidates were able to state that something would contain the same number of protons but different numbers of neutrons. Frequently, reference was made to elements, nuclides or atoms, rather than nuclei.

(b) With few exceptions, the decay constant λ was calculated correctly but without any statement that this constant is the probability of decay per unit time.

(c) (i) This part was answered correctly by most candidates. A minority assumed A_0 to be 7.4 MBq and thus calculated the initial activity to be less than that after 21 days.

(ii) Although many candidates could correctly calculate the number of nuclei, they were unable to convert this number to a mass in grams.

Section B

Question 9

(a) The great majority of candidates were able to state at least three properties.

(b) Despite being told that the question is based on a comparator, very few candidates produced a square-wave graph; most opted for a sinusoidal curve.

(c) Many candidates were not familiar with the accepted symbol for an LED. Most drew some component between V_{OUT} and the earth line.

Question 10

(a) In general, attenuation or absorption was mentioned. Those who stated that point B is at a greater distance than point A were not given credit unless it was also stated that the beam is either parallel or divergent.

(b) (i) Many candidates calculated the inverse of the expected ratio.

(ii) A common error was to calculate the ratios for the bone and the soft tissue and then to add these two quantities, rather than find the product.

(c) Most candidates did not consider the two ratios when answering this part. Rather, they commented on the two values of μ, without any consideration of the thickness or composition.

Question 11

(a) This part was answered well by most candidates.

(b) Only a few candidates understood this part. Whilst it was realised that a digital signal consists of series of 'highs' and 'lows', a widespread misconception was that only these 'highs' and 'lows' are amplified.

(c) The majority of answers given here were correct. The most common error was to invert the equation, leading to an answer of 7.6×10^{22} W for the attenuated signal.

Question 12

(a) Both **(i)** and **(ii)** were answered correctly by almost all candidates.

(b) (i) A frequent answer was to enable the phone to be switched on and off. The use of a single aerial was often omitted when reference was made to a signal being received or transmitted.

(ii) There were very few adequate answers. Some thought that the converter converted an analogue signal to a digital signal. Others stated that the data would be sent out as a series of bits. Seldom was the point made that all the bits of one number arrive at the same time, and then these bits are sent out one after another.

PHYSICS

Paper 9702/43

A2 Structured Questions

Key Messages

- Candidates should be encouraged to practise writing several sentences of continuous prose to give explanations of different phenomena in physics. Many examples of such exercises are to be found in past examination papers.

- Candidates should be reminded to pay close attention to the prefixes of units in order to prevent power-of-ten errors occurring in calculations. A quick check on whether an answer is 'reasonable' would allow candidates to detect errors in their working.

- Most candidates could improve their performance by learning the precise details of definitions and laws required by the syllabus. Quantities are defined in terms of other quantities, and do not depend on units.

General Comments

The paper challenged the most able candidates, while still providing the weaker candidates with ample opportunities to score credit.

Although there were many good answers, there were comparatively few candidates whose performance over the entire paper was consistently good, with many performing slightly better on ***Section A*** than on ***Section B***. Most candidates would benefit from having a deeper understanding of the production and use of X-rays.

Candidates should be advised that credit is awarded not only for final answers, but also for the way in which problems are approached. It is essential that all working is clearly presented so that each step in a calculation is shown explicitly.

Comments on Specific Questions

Section A

Question 1

(a) There were many good answers. A common error was to refer to one kilogram instead of unit mass.

(b) Many candidates correctly explained that gravitational force is always attractive. However, few went on to explain that a body in the gravitational field will do work as it moves from infinity.

(c) There was more than one method of deriving the correct expression. Most candidates considered the work done to move the small mass by a short distance. In order to gain full credit, candidates needed to show each step in their derivation and fully explain any approximations that are used. Candidates also needed to explain any symbols that were not explained in the stem of the question.

(d) The calculation presented few problems for well-prepared candidates. However, a significant minority equated an expression for the gravitational force to an inappropriate expression of centripetal force. Others confused the planet's radius with its diameter.

Question 2

(a) (i) With few exceptions, a correct answer was given.

(ii) Candidates needed to make it clear that it is the total volume of all the molecules, rather than the volume of a single molecule, that is negligible compared to the volume of the containing vessel.

(b) Many candidates need to improve their understanding of the kinetic theory of gases. The velocity of a molecule was often confused with a component of its velocity. Few candidates distinguished between the square speed of a single molecule and the mean square speed of all the molecules.

(c) Although there were many successful calculations, others confused mean square speed with root mean square speed or omitted the conversion of temperature from degrees Celsius to kelvin.

Question 3

(a) A correct definition was usually given. The most common error was to define either specific latent heat of fusion or specific latent heat of vaporisation, rather than specific latent heat in general.

(b) Candidates calculated the final answer in one of two ways. The first way was to find the total loss in energy after two minutes and then convert this to a rate of energy loss. The second way was to find the power needed for evaporation and then subtract this from the power supplied by the kettle.

Question 4

(a) Most calculations were successful. A small minority confused the displacement of the ball with its amplitude of oscillation.

(b) There were few fully correct responses. The speed of the ball is a sine function. Squaring this sine function to obtain kinetic energy will result in a sinusoidally shaped wave of double the frequency.

Question 5

(a) The definition of electric field strength needed to be stated precisely. It is clearly defined in the syllabus as being the force per unit positive charge acting on a stationary point charge.

(b) (i) A high proportion of the candidates could recall the correct expression for the electric field strength, although the ensuing calculation often contained power-of-ten errors.

(ii) The vast majority of candidates correctly used the expression $V = \dfrac{Q}{4\pi\varepsilon_0 r}$. However, a small minority chose to use the expression $E = \dfrac{V}{r}$. In the general situation, field strength is not equal to the ratio of potential and radius, but rather $E = \Delta V/\Delta d$. It happens to be that for an isolated point charge the expression $E = \dfrac{V}{r}$ is valid, but any candidate wishing to use that expression must clearly explain the reason for its validity.

Question 6

(a) Parts **(i)** and **(ii)** were well answered. In part **(iii)**, a common error was to use a period of 10 ms.

(b) Parts **(i)** and **(ii)** were usually answered successfully. The calculation in part **(iii)** proved to be more problematic, with few candidates using the correct discharge time of 7 ms.

(c) Very few candidates realised that, for a single discharge, the average potential difference across the resistor is 3.2 V.

Question 7

(a) Most drawings showed the magnetic field lines as concentric circles in the correct direction. Candidates should be advised that a change in the spacing of the magnetic field lines indicates a change in the magnetic field strength. Most candidates needed to be more careful when drawing the increasing separation of the field lines as the distance from the wire increases.

(b) (i) The direction of the force on wire B was usually indicated correctly.

(ii) Only a small minority of answers correctly explained that the force on wire A is equal to the force on wire B, as outlined in Newton's third law. A few answers gave an alternative explanation that the force on each wire is dependent on the product of the two currents.

(c) Candidates are advised to note the credit allocation for each question part as this is a guide to the depth required for the answer. The majority of answers described only one aspect of the force. The most common response was to state that the force would always be attractive. It was seldom stated that the variation of the force would be sinusoidal at double the frequency of the current.

Question 8

(a) Most candidates could recall that a photon is a quantum of energy of electromagnetic radiation. Only a small minority explained that this energy is equal to the Planck constant multiplied by the frequency. A statement of the algebraic expression needed to be accompanied by an explanation of all symbols.

(b) When describing the process of photon emission, candidates must distinguish between energy levels and the change between energy levels. Many candidates incorrectly associate a photon of a specific wavelength to a specific energy level.

Question 9

(a) (i) The majority of candidates could correctly define the decay constant as being the probability of decay of a nucleus per unit time.

(ii) Candidates should be advised that it is essential that every step in a derivation is shown explicitly. Weaker candidates often presented intermediate expressions that did not distinguish between either N and N_0 or t and $t_{½}$.

(b) Most calculations were successful.

(c) The random nature of decay and the effect of background radiation were usually identified correctly. A significant number of answers incorrectly referred to the effect of environmental factors, such as temperature.

Section B

Question 10

(a) Almost without exception, the light-dependent resistor was identified correctly.

(b) The two resistors were frequently drawn in the correct configuration. However, the relay was usually connected wrongly and not represented by the correct symbol.

(c) (i) Candidates sometimes stated the purpose of a relay in general terms, rather than stating the purpose of the relay when used in the given circuit.

(ii) Only a small proportion of the candidates understood that the diode is connected in the direction shown to ensure that the relay switches on the lamp only when the output of the operational amplifier becomes negative.

Question 11

(a) (i) Answers needed to include a clear statement that X-ray photons are produced when the electrons are decelerated. Very few answers explained that the X-rays present a continuous distribution of wavelengths because the electrons undergo a range of decelerations at the anode.

(ii) Many candidates were unable to explain that the sharp cut-off at short wavelength corresponds to an electron 'losing' all of its energy in one collision to produce a single photon. Less able candidates sometimes gave irrelevant explanations of either the characteristic X-ray spectrum or the threshold wavelength in the photoelectric effect.

(b) It was generally appreciated that *hardness* is a measure of the penetration of the beam and that the hardness is controlled by changing the accelerating voltage. However, despite the credit allocation for this part of the question, there were few answers that went on to explain that increased hardness is associated with increased penetration and increased accelerating voltage. A common error was to confuse the hardness of an X-ray beam with its intensity.

(c) (i) The majority of candidates realised that long-wavelength X-ray radiation is more likely to be absorbed in the body. However, a common misconception was that the longer wavelength X-ray photons posed a greater health hazard because they had greater energy.

(ii) A high proportion of the candidates knew that the hazard would be minimised by the use of an aluminium filter in the X-ray beam. However, there were also inappropriate references to the use of a grid.

Question 12

(a) Most candidates did refer to a strong uniform magnetic field and a calibrated non-uniform magnetic field. However, the purpose of these two fields was not always made clear.

(b) There were many well-explained solutions to both parts **(i)** and **(ii)**.

Question 13

(a) (i) Although the majority of candidates understood that neighbouring cells use different carrier frequencies in order to avoid interference, few realised that this interference would occur near to cell boundaries.

(ii) It was seldom appreciated that in order for the cells to have a larger area, it is necessary to increase the signal strength and that this might be hazardous to health. Some candidates thought, incorrectly, that the cell size was determined solely by the 'line of sight' of the signals so that the cell area would extend all the way to the horizon.

(b) The majority of candidates realised that the mobile phone handset continues to send out an identifying signal. Thus, the computer at the cellular exchange continually selects the base station with the strongest signal and allocates a carrier frequency. Poor answers often confused the roles of the different parts of the mobile phone system.

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.
- To score well in **Question 1**, candidates must ensure that their responses answer the question set and include detailed explanations.
- Graphical work should be carefully attempted and checked. Candidates are advised to use a clear 30 cm ruler to draw straight lines.
- To gain credit in the numerical answers towards the end of **Question 2**, it is important that candidates show all their working.
- The practical skills required for this paper should be developed and practised over a period of time with a 'hands-on' approach in order to achieve a high score.

General comments

Some candidates scored very highly, although a few candidates were unable to receive any credit.

Question 2 was generally answered better than **Question 1** and a large number of candidates scored very highly. A number of candidates had difficulty determining the *y*-intercept and using it correctly in the final analysis section. For **Question 1** many candidates did not understand that the situation was dynamic as opposed to static; furthermore, a number of candidates were confused between oscillations and rotations. In **Question 1**, candidates should include greater detail in their answers, while for **Question 2** careless mistakes were often made in the plotting of points on the graph and drawing lines that were not straight. The Examiner's use box at the end of **Question 1** should provide a useful hint to candidates about the criteria used for awarding credit.

To assist Centres, Cambridge have produced two booklets – Teaching AS Physics Practical Skills and Teaching A2 Physics Practical Skills that are available from the Teacher Support Website

Comments on specific questions

Question 1

Candidates were required to design a laboratory experiment to investigate how the angle to the vertical varies when the central pole rotates at different angular velocities.

Candidates are advised to begin 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. Credit was awarded for correctly identifying the independent and dependent variables. Many candidates correctly realised that the frequency or period of rotation was the independent variable and the angle was the dependent variable. Some candidates, however, stated that the angle was the variable to be changed, which would be difficult to do experimentally. Further credit was awarded to candidates who clearly indicated how the angular velocity would be determined in terms of either the frequency or the period of oscillation. Candidates who stated that the length of the rigid rod needed to be kept constant, received further credit; the word "controlled" is not an acceptable alternative to the word "constant".

Candidates were expected to draw a clearly labelled diagram of the arrangement of their equipment suitable for this investigation. In this experiment candidates were expected to include in their diagram the method of rotating the metal pole and some indication of how the speed of the rotating device could be changed; candidates who used an electric motor were invariably awarded credit. To determine the angular velocity, candidates needed to determine either the frequency of the rotation or the time period of the rotation. Many candidates indicated that they would use a stopwatch to time a number of rotations, other candidates used a rev counter. Candidates who made vague references to light gates, cathode-ray oscilloscopes and computers were not credited. In this investigation there is a need to carry out measurements at a particular point and thus good candidates discussed the use of a fiducial mark or the use of light gates perpendicular to the motion of the object. Further credit was awarded to candidates who discussed ways in which the angle could be measured; suggestions involving the use of a protractor, possibly fixed to the pole, were awarded credit. Where trigonometry methods were suggested, it was expected that candidates would use a ruler or rule to measure the appropriate distances; extra credit was available for explaining how the cosine of the angle was determined using distances. Many candidates did not seem familiar with the word "protractor"; there were many different spellings and some diagrams referred to "angle measurers".

Credit was available for the analysis of the data. It was expected that candidates would state the quantities that should be plotted on each axis of a graph. Many candidates suggested plotting a graph of $\cos\theta$ against $1/\omega^2$; other logically valid graphs were credited. A large number of candidates did not understand the term 'inversely proportional'; these candidates often incorrectly suggested plotting a graph of $\cos\theta$ against ω^2 and then stated that the negative gradient of this graph confirms the inverse proportionality. Candidates were awarded credit 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 suggested plotting logarithmic graphs. Candidates were expected to state that the relationship would be valid if a straight line was produced, and also to include the appropriate gradient value of the line.

Credit was 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; vague answers did not gain credit. Creditworthy responses included the use of a safety screen in case the small object detached; credit was not awarded for standing away from the apparatus or for wearing goggles.

Candidates should be encouraged to write their plans including appropriate detail; there was some evidence of candidates lacking sufficient practical experience. Vague responses could not be credited. In addition to the points already mentioned above, credit was also given for:

- the use of a large motor speed to produce measurable angles;
- additional detail on measuring the angle by using a projection method, slow motion freeze frame video or camera, with clear explanations;
- a method to check that the pole is vertical
- additional detail on measuring the angular velocity, e.g. timing at least ten rotations;
- waiting for the motion to be come stable.

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

Question 2

In this data analysis question candidates were given data concerning the vertical deflection of a wire when a current flows through it.

(a) A significant number of candidates were able to correctly determine expressions for the gradient and y-intercept of a graph of lg y against lg I from a given equation.

(b) Many candidates did not realise that for logarithmic quantities the number of significant figures corresponds to the number of decimal places in the logarithmic quantity. It is expected that the number of decimal places in the logarithmic quantity should be the same as or one more than the number of significant figures in the raw data. Thus when I has a value of 95, which is two significant figures, lg (I) should be given as either 1.98 (two decimal places) or 1.978 (three decimal places). The absolute uncertainties in lg y were usually calculated correctly. The Examiners allowed different methods for finding uncertainties and did not penalise significant figures at this stage.

(c) (i),(ii) The graph plotting was quite variable. Common mistakes included not plotting the points correctly, although it was pleasing to see that there were fewer large plot points. Candidates should be encouraged to check plots that do not appear to follow the line of best fit. Similarly, a number of candidates did not construct the error bars accurately. Most candidates attempted to draw the line of best fit. The worst acceptable straight line should be either the steepest possible line or the shallowest possible line that passes through the error bars of all the data points used for the line of best fit. The majority of the candidates clearly labelled the lines on their graph; in future lines not indicated will not receive credit. A number of candidates could not be awarded credit for their lines since they were not straight. In many cases it would appear that the candidates were using a 15 cm ruler, thus making it impossible to draw the line in one go, and often meant that the resultant line was not straight; candidates should be encouraged to use a clear 30 cm ruler.

(iii) This part was generally answered well, although in some case the working could have been 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 had used from the line of best fit. Some candidates were confused by the labelling of the axis for lg I and 10^{-2} appeared in the calculation. To determine the absolute error in the gradient, candidates were expected to find the difference between the gradient of the line of best fit and the gradient of the worst acceptable line. Again good candidates clearly indicated the points that they had used from the worst acceptable line.

(iv) A large number of candidates did not realise that there was a false origin. Good candidates substituted a point from the line of best fit, often from their gradient calculation, into $y = mx + c$. To determine the uncertainty in the y-intercept, candidates had to determine the worst acceptable y-intercept by using the gradient from the worst acceptable line and a point on the worst acceptable line. Ratio methods cannot be used to find the uncertainty in the y-intercept.

(d) Candidates had to give r within a specified range and to an appropriate number of significant figures to gain credit. Candidates needed to determine s using their value for the y-intercept. Many candidates clearly showed their working and did this correctly; others were confused. Substitution methods were not creditworthy. To determine the uncertainty in s, many candidates tried incorrectly to use a ratio method. Candidates should be encouraged to clearly show their working at this stage.

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.
- To score well in **Question 1**, candidates must ensure that their responses answer the question set and include detailed explanations.
- Graphical work should be carefully attempted and checked. Candidates are advised to use a clear 30 cm ruler to draw straight lines.
- To gain credit in the numerical answers towards the end of **Question 2**, it is important that candidates show all their working.
- The practical skills required for this paper should be developed and practised over a period of time with a 'hands-on' approach in order to achieve a high score.

General comments

Some candidates scored very highly, although a few candidates were unable to receive any credit.

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 full credit. For **Question 1**, candidates should include greater detail in their answers, while for **Question 2** careless mistakes were often made in the plotting of points on the graph and drawing lines that were not straight. Furthermore **2(d)** was poorly answered; the unit was often omitted and determination of the percentage uncertainty incorrectly calculated. The Examiner's use box at the end of **Question 1** should provide a useful hint to candidates about the criteria used for awarding credit.

It is clear that the better candidates 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 angle to the horizontal of a string attached to a helium balloon varies when the balloon is subjected to different air speeds.

Candidates are advised to begin 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. Credit was awarded for correctly identifying the independent and dependent variables. Many candidates correctly realised that the speed of air flow was the independent variable and the angle was the dependent variable. Further credit was awarded to candidates who stated that the volume, or mass, of the balloon and the temperature needed to be kept constant; the word "controlled" is not an acceptable alternative to the word "constant".

Candidates were expected to draw a clearly labelled diagram of the arrangement of their equipment suitable for this investigation. In this experiment candidates were expected to include in their diagram the method of producing 'wind'. Most candidates used an electric fan. It was expected that the fan would be approximately horizontal with the balloon. Credit was awarded to candidates who had a small mass attached to the balloon. Further credit was then awarded for describing the method that would be used to change to wind speed and how the wind speed could be measured. Many candidates discussed changing the power setting of the fan or using rheostats or variable power supplies. Some candidates correctly referred to anemometers; other basic devices were also accepted. Credit was available for measuring the air speed at the point where the balloon was positioned. Further credit was awarded to candidates who discussed how the angle could be measured; suggestions involving the use of a protractor, often specifying a large protractor, or describing projection methods, were awarded credit. Where trigonometry methods were suggested, it was expected that candidates would use a ruler or rule to measure the appropriate distances; extra credit was available for explaining how the tangent of the angle was determined using distances. Many candidates did not seem familiar with the word "protractor"; there were many different spellings and some diagrams referred to "angle measurers".

Credit was available for the analysis of the data. It was expected that candidates would state the quantities that should be plotted on each axis of a graph. Many candidates suggested plotting a graph of $\tan\theta$ against $1/v^2$; other logically valid graphs were credited. A large number of candidates did not understand the term 'inversely proportional'; these candidates often incorrectly suggested plotting a graph of $\tan\theta$ against v^2 and then stated that the negative gradient of this graph confirms the inverse proportionality. Candidates were awarded credit 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 suggested plotting logarithmic graphs. Candidates were expected to state that the relationship would be valid if a straight line was produced with the correct gradient.

Credit was 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; vague answers did not gain credit. Creditworthy responses included the use of a safety screen to avoid the moving blades of the fan or wearing goggles to avoid air stream or particles entering the eyes; credit was not awarded for standing away from the experiment or for stating 'goggles' without reasoning.

There are four marks available for additional detail; there was some evidence of candidates lacking sufficient practical experience. Vague responses could not be credited. In addition to the points already mentioned above, credit was also given for:

- the use of large wind speeds to produce measurable angles or a large cross-sectional area of the balloon;
- adjusting the height of the fan so that the air flow is horizontally aligned to the balloon;
- a reason for adding mass to the balloon;
- a method to avoid draughts, e.g. use of wind tunnel, keep windows shut;
- waiting for the balloon to become stable.

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

Question 2

In this data analysis question candidates were given data on how the resonant length L of a wire varied with frequency f.

(a) Candidates were asked to determine an expression for the gradient if a graph of f against $1/L$ was plotted. This was generally well answered. This first part was important since it should have helped candidates in many later parts of the question.

(b) Most candidates correctly included the column heading $(1/L)/\text{m}^{-1}$, although some candidates did not include a distinguishing mark between quantity and unit. Other candidates included 10^2 or 10^{-2} in the heading. The calculated and recorded values of $1/L$ 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 or one more that the number of significant figures in the raw data. The absolute uncertainties in $1/L$ were usually calculated correctly. The Examiners allow a number of different methods and do not penalise significant figures at this stage.

(c) (i),(ii) The graph plotting was quite variable. Common mistakes included not plotting the points correctly; candidates should check suspect plots. A number of candidates did not plot $1/L$ correctly for the value of f = 440 Hz. Candidates should also be advised to ensure that the size of the plots are small; large plot points do not receive credit. Candidates should be encouraged to check plots that do not appear to follow the line of best fit. Similarly a number of candidates did not construct the error bars accurately; a significant number of candidates incorrectly plotted vertical error bars. Most candidates attempted to draw the line of best fit. The worst acceptable straight line should be either the steepest possible line or the shallowest possible line that passes through the error bars of all the data points used for the line of best fit. The majority of the candidates clearly labelled the lines on their graph; in future lines not indicated will not receive credit. A number of candidates could not be awarded credit for their lines since they were not straight. In many cases it would appear that the candidates were using a 15 cm ruler, thus making it impossible to draw the line in one go, and often meant that the resultant line was not straight; candidates should be encouraged to use a clear 30 cm ruler.

(iii) This part was generally answered well, although in some case the working could have been 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 had used from the line of best fit. Some candidates used their points from the table but did not gain credit because they did not lie on the line of best fit. To determine the 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 had used from the worst acceptable line.

(d) (i) Candidates should have determined a value for μ with an appropriate unit. Candidates often gained the credit for the value of μ but failed to give the correct unit. Some candidates realised that the unit should have been $\text{kg}\,\text{m}^{-1}$ while others correctly worked it out from the gradient and obtained $\text{N}\,\text{Hz}^{-2}\,\text{m}^{-2}$. A large number of candidates omitted the unit. The most common error seen in the unit was where candidates to forgot that the gradient needed to be squared, and thus gave the unit incorrectly as $\text{N}\,\text{Hz}^{-1}\,\text{m}^{-1}$.

(ii) There were a number of possible ways of answering this part. Good candidates clearly showed their working. The simplest method was to add the percentage uncertainty in T (10%) to twice the percentage uncertainty in the gradient. The common error with this method was to not double the percentage uncertainty in the gradient. Some candidate remembered to double the percentage uncertainty in the gradient but then subtracted from it the percentage uncertainty in T. Candidates who calculated a worst acceptable value of μ had to remember that either the maximum value of T should to be used with the minimum value of gradient, or the minimum value of T used with the maximum value of gradient.

(e) (i) It was pleasing to see many answers given within the allowed range; answers also had to be given to an appropriate number of significant figures.

(ii) Candidates were required to determine the percentage uncertainty in r. The simplest method was to halve the answer to **(d)(ii)**. Many candidates clearly demonstrated this process. A common error was to double **(d)(ii)**. Other candidates carefully worked through the uncertainty in μ to determine the worst acceptable value for μ. It is essential that candidates clearly show their working, particularly to questions such as **(d)(ii)** and **(e)(ii)**.

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.
- To score well in **Question 1**, candidates must ensure that their responses answer the question set and include detailed explanations.
- Graphical work should be carefully attempted and checked. Candidates are advised to use a clear 30 cm ruler to draw straight lines.
- To gain credit in the numerical answers towards the end of **Question 2**, it is important that candidates show all their working.
- The practical skills required for this paper should be developed and practised over a period of time with a 'hands-on' approach in order to achieve a high score.

General comments

Some candidates scored very highly, although a few candidates were unable to receive any credit.

Question 2 was generally answered better than **Question 1** and a large number of candidates scored very highly. A number of candidates had difficulty determining the *y*-intercept and using it correctly in the final analysis section. For **Question 1** many candidates did not understand that the situation was dynamic as opposed to static; furthermore, a number of candidates were confused between oscillations and rotations. In **Question 1**, candidates should include greater detail in their answers, while for **Question 2** careless mistakes were often made in the plotting of points on the graph and drawing lines that were not straight. The Examiner's use box at the end of **Question 1** should provide a useful hint to candidates about the criteria used for awarding credit.

To assist Centres, Cambridge have produced two booklets – Teaching AS Physics Practical Skills and Teaching A2 Physics Practical Skills that are available from the Teacher Support Website

Comments on specific questions

Question 1

Candidates were required to design a laboratory experiment to investigate how the angle to the vertical varies when the central pole rotates at different angular velocities.

Candidates are advised to begin 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. Credit was awarded for correctly identifying the independent and dependent variables. Many candidates correctly realised that the frequency or period of rotation was the independent variable and the angle was the dependent variable. Some candidates, however, stated that the angle was the variable to be changed, which would be difficult to do experimentally. Further credit was awarded to candidates who clearly indicated how the angular velocity would be determined in terms of either the frequency or the period of oscillation. Candidates who stated that the length of the rigid rod needed to be kept constant, received further credit; the word "controlled" is not an acceptable alternative to the word "constant".

Candidates were expected to draw a clearly labelled diagram of the arrangement of their equipment suitable for this investigation. In this experiment candidates were expected to include in their diagram the method of rotating the metal pole and some indication of how the speed of the rotating device could be changed; candidates who used an electric motor were invariably awarded credit. To determine the angular velocity, candidates needed to determine either the frequency of the rotation or the time period of the rotation. Many candidates indicated that they would use a stopwatch to time a number of rotations, other candidates used a rev counter. Candidates who made vague references to light gates, cathode-ray oscilloscopes and computers were not credited. In this investigation there is a need to carry out measurements at a particular point and thus good candidates discussed the use of a fiducial mark or the use of light gates perpendicular to the motion of the object. Further credit was awarded to candidates who discussed ways in which the angle could be measured; suggestions involving the use of a protractor, possibly fixed to the pole, were awarded credit. Where trigonometry methods were suggested, it was expected that candidates would use a ruler or rule to measure the appropriate distances; extra credit was available for explaining how the cosine of the angle was determined using distances. Many candidates did not seem familiar with the word “protractor”; there were many different spellings and some diagrams referred to “angle measurers”.

Credit was available for the analysis of the data. It was expected that candidates would state the quantities that should be plotted on each axis of a graph. Many candidates suggested plotting a graph of $\cos\theta$ against $1/\omega^2$; other logically valid graphs were credited. A large number of candidates did not understand the term ‘inversely proportional’; these candidates often incorrectly suggested plotting a graph of $\cos\theta$ against ω^2 and then stated that the negative gradient of this graph confirms the inverse proportionality. Candidates were awarded credit 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 suggested plotting logarithmic graphs. Candidates were expected to state that the relationship would be valid if a straight line was produced, and also to include the appropriate gradient value of the line.

Credit was 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; vague answers did not gain credit. Creditworthy responses included the use of a safety screen in case the small object detached; credit was not awarded for standing away from the apparatus or for wearing goggles.

Candidates should be encouraged to write their plans including appropriate detail; there was some evidence of candidates lacking sufficient practical experience. Vague responses could not be credited. In addition to the points already mentioned above, credit was also given for:

- the use of a large motor speed to produce measurable angles;
- additional detail on measuring the angle by using a projection method, slow motion freeze frame video or camera, with clear explanations;
- a method to check that the pole is vertical
- additional detail on measuring the angular velocity, e.g. timing at least ten rotations;
- waiting for the motion to be come stable.

Usually good candidates who have followed a ‘hands on’ practical course during their studies are able to score this additional credit. It is essential that candidates’ answers give detail relevant to the experiment in the question rather than ‘text book’ rules for working in a laboratory.

Question 2

In this data analysis question candidates were given data concerning the vertical deflection of a wire when a current flows through it.

(a) A significant number of candidates were able to correctly determine expressions for the gradient and y-intercept of a graph of lg y against lg I from a given equation.

(b) Many candidates did not realise that for logarithmic quantities the number of significant figures corresponds to the number of decimal places in the logarithmic quantity. It is expected that the number of decimal places in the logarithmic quantity should be the same as or one more than the number of significant figures in the raw data. Thus when I has a value of 95, which is two significant figures, lg (I) should be given as either 1.98 (two decimal places) or 1.978 (three decimal places). The absolute uncertainties in lg y were usually calculated correctly. The Examiners allowed different methods for finding uncertainties and did not penalise significant figures at this stage.

(c) (i),(ii) The graph plotting was quite variable. Common mistakes included not plotting the points correctly, although it was pleasing to see that there were fewer large plot points. Candidates should be encouraged to check plots that do not appear to follow the line of best fit. Similarly, a number of candidates did not construct the error bars accurately. Most candidates attempted to draw the line of best fit. The worst acceptable straight line should be either the steepest possible line or the shallowest possible line that passes through the error bars of all the data points used for the line of best fit. The majority of the candidates clearly labelled the lines on their graph; in future lines not indicated will not receive credit. A number of candidates could not be awarded credit for their lines since they were not straight. In many cases it would appear that the candidates were using a 15 cm ruler, thus making it impossible to draw the line in one go, and often meant that the resultant line was not straight; candidates should be encouraged to use a clear 30 cm ruler.

(iii) This part was generally answered well, although in some case the working could have been 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 had used from the line of best fit. Some candidates were confused by the labelling of the axis for lg I and 10^{-2} appeared in the calculation. To determine the absolute error in the gradient, candidates were expected to find the difference between the gradient of the line of best fit and the gradient of the worst acceptable line. Again good candidates clearly indicated the points that they had used from the worst acceptable line.

(iv) A large number of candidates did not realise that there was a false origin. Good candidates substituted a point from the line of best fit, often from their gradient calculation, into $y = mx + c$. To determine the uncertainty in the y-intercept, candidates had to determine the worst acceptable y-intercept by using the gradient from the worst acceptable line and a point on the worst acceptable line. Ratio methods cannot be used to find the uncertainty in the y-intercept.

(d) Candidates had to give r within a specified range and to an appropriate number of significant figures to gain credit. Candidates needed to determine s using their value for the y-intercept. Many candidates clearly showed their working and did this correctly; others were confused. Substitution methods were not creditworthy. To determine the uncertainty in s, many candidates tried incorrectly to use a ratio method. Candidates should be encouraged to clearly show their working at this stage.