

PHYSICS

Paper 9702/11
Multiple Choice

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

General Comments

This paper demands quick and accurate working by candidates. Many questions can be answered relatively quickly and this gives more time to spend on the more involved questions. Candidates should be advised never to spend a disproportionately long time on any one question. Candidates should be encouraged to use the spaces on the question paper for their working. Care with units is essential. Prefix errors are a cause of many wrong answers as are corresponding powers of 10 errors.

Comments on Specific Questions

Question 4

Many candidates added all the figures in the question and gave **C** as their answer. To obtain the correct answer, candidates needed to realise that the diameter is squared and so it contributes 3% to the overall uncertainty. This makes **D** the correct answer.

Question 5

Candidates found this question difficult, perhaps because they had to work algebraically rather than arithmetically. Candidates would benefit from further practice of this type of algebraic question.

Question 9

In answering this type of question, it is essential that candidates do working and draw a diagram. A common incorrect answer was **D**, which was obtained by ignoring the directions altogether.

Question 11

As weight is the only downward force, it must be the largest of the three. The upthrust in air is very small so **A** must be the correct answer, but both **B** and **D** were common answers given. Candidates would benefit from sketching a force diagram when answering this type of question. This takes only a few seconds and would help candidates to deduce the right answer.

Question 12

The key to this question is first to find a suitable point about which to take moments. Moments about the top of the ladder give the required equation directly. There is no need to involve any angles when the forces are all given.

Question 16

Candidates found this question difficult. With a 45° take-off, the vertical and the horizontal velocities are identical, so each contributes half the total kinetic energy. At the highest point there is no vertical movement but the horizontal velocity is unchanged, so **A** is correct.

Question 21

Candidates would benefit from drawing on this graph. A horizontal line at about 6 N shows approximately the same area as under the whole graph. This gives $6 \text{ N} \times 0.3 \text{ m} = 1.8 \text{ J}$.

Question 23

The key here is to realise that maximum displacement corresponds with minimum speed. This can be deduced by considering the gradient of the displacement graph.

Question 26

There will be no place where the sound intensity is exactly zero, because loudspeakers are not point sources of sound. Answers **B** and **C** cannot be correct. The maxima gradually decrease in intensity away from the central maximum because the individual amplitudes of the two sound waves decrease with distance.

Question 30

This question must be answered with reference to p.d. Initially the p.d. across B_2 is low and therefore the p.d. across B_1 is high. On opening the switch these become equal, which gives **B** as the correct answer.

Question 33

This question was found to be very difficult. The thickest conductor has the least resistance, so the smallest voltage drop occurs across the thickest conductor. The stepped changes in **C** and **D** are unphysical so the correct answer must be **A**.

Question 34

The resistance is V/I and is least at **C**. Candidates should be reminded that the resistance is not related to the gradient of the line.

Question 38

The responses to this question suggested that many candidates attempted to guess the answer. These candidates would benefit from further study of the properties of radiation.

PHYSICS

Paper 9702/12
Multiple Choice

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

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PHYSICS

Paper 9702/13
Multiple Choice

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1	A	21	B
2	C	22	A
3	A	23	C
4	D	24	B
5	D	25	C
6	D	26	A
7	D	27	A
8	A	28	C
9	C	29	C
10	B	30	D
11	B	31	D
12	C	32	C
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Comments on Specific Questions

Question 3

A common incorrect answer was **B**. The resistance falls rapidly with temperature at low temperatures, so the current will rise rapidly. The resistance curve becomes flatter at higher temperatures, so the current will change more slowly with temperature.

Question 4

Candidates need to be careful with instrument readings from scales. Many just read in whole numbers but scales can usually be read to at least a half a division. Here it was expected therefore that candidates would give 24.0 ± 0.5 , making the last figure in the value correspond to the single figure in the error estimation.

Question 7

At the extremes of the motion, the velocity changes direction, so the answer must be **B** or **D**. At the lowest point, the mass is about to move upwards, which gives **D**. Many candidates chose other incorrect answers.

Question 11

This question was difficult but discriminated well. Each speed is given by $\sqrt{2gh}$. The velocity changes direction so there must be a plus sign between the two terms. The two terms must be well separated and not enclosed by a single square root sign.

Question 17

This question was found to be relatively difficult, and both **B** and **C** were commonly chosen. The loss of potential energy is 240 J and the work done against friction is $10 \text{ N} \times 16 \text{ m} = 160 \text{ J}$, so **A** is correct.

Question 19

This question has similar ideas to those in **Question 17** but they were presented in a different way. The quantities were clearly defined in the question stem, but perhaps candidates did not read Δ as 'change in'. Answer **D** as 'the change in kinetic energy equals zero' is correct for a van travelling at a constant speed.

Question 22

Considering the level at which the two liquids meet, it is clear that the density of P is half the density of Q. A common incorrect answer was **B**.

Question 24

Many candidates seemed to misread the helpful hint, and incorrectly thought that considering XY as a straight line was to treat the entire graph as a straight line from O to Y. These candidates obtained **A**. A straight line from X to Y gives the correct answer **B**.

Question 27

This question was found to be difficult, and the incorrect answer **C** was given by many candidates. The distance of 10.0 cm is **not** the wavelength of the wave. The distance between two nodes on a stationary wave is half the wavelength, so the wavelength is 20.0 cm and the corresponding frequency is 1700 Hz.

Question 34

Many candidates chose **A** or **D**. They saw that the e.m.f. will be recorded first and will be constant. To distinguish between the *I* and *R* columns, one method is to consider that the voltage drop due to internal resistance must be larger when the current is greater, so the first row of data is for a greater current than the second row. Therefore, **D** is correct.

Question 37

This question required careful working. The combined resistance of the left-hand section is 2Ω and the combined resistance of the right-hand section is 1Ω , so $V_1 > V_2$. In the right-hand section, each parallel branch has half of the total current, while in the left-hand section there is more current in the 3Ω resistor than in the 6Ω resistor. This gives $I_1 > I_2$, so the correct answer is **A**.

PHYSICS

<p>Paper 9702/21 AS Structured Questions</p>
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Key Messages

- Candidates should choose their wording carefully, especially when giving a definition or describing a situation. Often answers are made unclear through the omission of certain key words and inappropriate use of everyday language.
- Candidates should be encouraged to consider whether the answers they have obtained to numerical questions are sensible. A simple arithmetical error can often be detected through a consideration of the answer.
- Some credit is awarded for the application and extension of the content of the syllabus. In order to score highly, candidates need to have a thorough understanding of the subject matter so that they can discuss sensibly situations that are based on the theoretical work.

General Comments

The questions that required a written response were generally less well answered than those questions that required calculations.

Some candidates do not show substitutions into formulae, or do not show them sufficiently neatly. This can often lead to avoidable arithmetical errors.

Responses to **Question 8** suggested that many candidates did not have a thorough understanding of stationary waves, and in particular did not appear to be familiar with experiments to demonstrate stationary waves. Candidates would benefit from further study of this section of the syllabus.

There was no evidence that an adequately prepared candidate did not have sufficient time to complete the question paper.

Comments on Specific Questions

Question 1

- (a) The majority of the candidates were able to name at least one base quantity.
- (b) A significant number of candidates were unable to give a clear statement of the base units for k . Many answers were given as 's/s' or this was cancelled down to a number, generally '1' or '0'. Candidates should be discouraged from drawing the conclusion that the unit has a numerical value.

Question 2

- (a) There were many definitions given that made no reference to the ratio between force and area. Candidates should be encouraged to give definitions as a precise statement.
- (b)(i) A significant number of candidates were able to gain partial credit. Some candidates made a mistake in using the diameter and not the radius when calculating the base area. Power-of-ten errors were also made in the conversion of cm^2 to m^2 . A few candidates did not calculate the weight of the cylinder but used the mass as the force acting on the surface.

- (ii) Many candidates did not appear to know how to calculate the actual uncertainty, and did not calculate fractional uncertainties for the mass and diameter. A small minority realised that the fractional uncertainty in the diameter should be doubled.
- (iii) Very few candidates were able to give a correct statement. The uncertainty should be expressed to one significant figure and the pressure quoted to the same power-of-ten as the uncertainty.

Question 3

- (a) A small minority of candidates were able to suggest that the scatter of points on the graph was due to random error.
- (b) Most candidates were able to determine the gradient.
- (c) The formula for resistivity was generally quoted correctly. The conversion of mm^2 to m^2 presented a difficulty for a significant number of candidates. The use of the gradient in the calculation was often ignored, and many candidates took values from the graph despite the existence of a systematic error in the readings.
- (d) There were very few correct answers. A significant number of candidates gave straight lines and often the resistance was shown to be increasing with an increase in cross-sectional area.

Question 4

- (a) (i) The majority of candidates were able to give the correct expression for acceleration and determined the accepted value. Some candidates did not include the initial velocity.
- (ii) The well prepared candidates were able to determine the distance moved by the trolley using a suitable equation for constant acceleration. Candidates should be encouraged to show clearly any substitutions so that arithmetical errors can be avoided.
- (iii) There were few correct answers. A significant number gave straight line graphs or curves with a decreasing gradient.
- (b) (i) The well prepared candidates gave the correct solution. There were a number of candidates who were unable to give correct expression for the component of the weight down the slope.
- (ii) There were few correct answers. A small minority of candidates were able to apply the equation that relates the resultant force to mass \times acceleration.

Question 5

- (a) (i) The majority of candidates gave the correct formula for the kinetic energy and determined the change in kinetic energy. There were a significant number who were not able to interpret the data given and use the values for the initial and final velocities during the relevant time.
- (ii) There were very few correct answers. The motion at constant speed was not recognised by the majority of candidates as being accompanied by zero change in kinetic energy.
- (iii) A minority of candidates were able to see that the change in kinetic energy was the same as in (i).
- (b) (i) The majority of candidates were able to give the appropriate formula for the potential energy. A small number were able to determine the height gained during the constant speed section and therefore go on to complete the calculation.
- (ii) The majority of candidates gained partial credit for an expression for power. There were very few candidates who then used force \times velocity or an equivalent formula to determine the power.

Question 6

There were some good responses. The majority of candidates gave responses that gained at least half of the available credit. In general there were few references to the effects of temperature on the two processes. Candidates should be made aware that the number of marks available is an indication of the detail required.

Question 7

- (a) A minority of candidates were able to explain the effect of the internal resistance on the e.m.f and terminal potential difference of a cell.
- (b)(i) The majority of candidates were able to quote the relevant formula ($V = IR$). There were many mis-readings from the graph for the value of the resistance, and many candidates left this part of the question blank.
- (ii) There were very few correct answers. A significant number gave no response. Only the well prepared candidates were able to apply the formula that relates e.m.f to the sum of the potential differences in the circuit.
- (iii) Only a minority of candidates realised that the power lost in the cell was determined by the internal resistance of the cell. Many candidates gave no response, or showed calculations using an incorrect resistance or potential difference value.
- (c) Very few candidates were aware that the 'lost volts' in a cell are determined by the current through the cell.

Question 8

- (a) The majority of candidates found it difficult to relate to the basic theory of the production of stationary waves. Those who made an attempt to give a description often gave vague answers. The majority of candidates did not seem to be well prepared for this particular question, so they would benefit from further study of stationary waves.
- (b)(i) A minority of candidates were able to interpret the waveform on the c.r.o. and determine the time period and hence the frequency. The majority appeared to have had little or no practice with this kind of question and, again, would benefit from further practice.
- (ii) A very small minority of candidates were able to demonstrate that they have experience of this experiment with stationary waves.
- (iii) There were many correct answers. The majority of candidates knew the appropriate formula and used the information given correctly.

PHYSICS

<p>Paper 9702/22 AS Structured Questions</p>
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Key Messages

- Candidates should choose their wording carefully, especially when giving a definition or describing a situation. Often answers are made unclear through the omission of certain key words and inappropriate use of everyday language.
- Candidates should be encouraged to consider whether the answers they have obtained to numerical questions are sensible. A simple arithmetical error can often be detected through a consideration of the answer.
- Some credit is awarded for the application and extension of the content of the syllabus. In order to score highly, candidates need to have a thorough understanding of the subject matter so that they can discuss sensibly situations that are based on the theoretical work.

General Comments

The questions that required a written response were generally less well answered than those questions that required calculations.

Some candidates do not show substitutions into formulae, or do not show them sufficiently neatly. This can often lead to avoidable arithmetical errors.

There was no evidence that an adequately prepared candidate did not have sufficient time to complete the question paper.

Comments on Specific Questions

Question 1

- (a) The majority of candidates were able to calculate the stress in units of Pa. A significant number of candidates found it difficult to make the conversion to units of GPa.
- (b)(i) The majority correctly calculated the wavelength in metres. The conversion to micrometres was often incorrect. A common incorrect approach was to multiply by 10^{-6} or divide by 10^6 and obtain an answer of 2.5×10^{-11} . Many of the candidates would benefit from using a systematic method of converting units from one power to another.
- (ii) The well prepared candidates were able to give the correct region of the electromagnetic spectrum. Many candidates were unable to use their answer in (i) to determine an appropriate region of the electromagnetic spectrum.
- (c)(i) Many candidates drew incorrect arrows for the direction of the resultant force. A significant number gave an arrow in the opposite direction to that required.
- (ii) 1. There were a variety of methods possible to show the value of the resultant force. Those that used a scale diagram often lost credit by not including a scale. A significant number of candidates successfully used either the cosine rule or resolution of forces and then Pythagoras' theorem.
2. This was well answered by the majority of candidates. A small number did not convert the units of mass from g to kg.

- (iii) The majority of candidates found it difficult to calculate the correct angle. There were a number of different approaches possible. Candidates should be encouraged to draw a sketch vector diagram to help with this kind of analysis.

Question 2

- (a) (i) The majority of answers were correct. There were some answers that gave the velocity at B as $+5.9 \text{ m s}^{-1}$ instead of -5.9 m s^{-1} .
- (ii) The majority of answers were correct. A significant minority assumed that the velocity of the ball was given on the graph rather than the vertical component and used an inappropriate value for the vertical component. Candidates often also made an error with the sign used for the acceleration in the equations of motion. Candidates should be encouraged to correctly link the sign of the vector with its magnitude when it is substituted into an equation. The most straightforward method using the area under the line proved to be the most successful for candidates.
- (iii) A small minority of candidates obtained the correct answer. Many of the incorrect answers were obtained assuming the vertical component of the velocity was the velocity of the ball.
- (iv) Very few candidates obtained credit. A significant number did not give any response even though they had an answer to (iii). Some of the candidates who did draw a line of constant velocity continued it past 1.2 s.
- (b) (i) The majority of candidates gave the correct formula for the kinetic energy. There were very few answers that used the maximum velocity. Many used either the horizontal component or more often the vertical component of the velocity.
- (ii) The majority of answers were correct.

Question 3

- (a) There were many definitions given that made no reference to a 'positive' charge or to the ratio. Candidates should be encouraged to give definitions as a precise statement.
- (b) The majority of candidates gave the relationship between density, mass and volume. Many also gave the correct expression for the volume of a sphere. A significant number missed out steps when substituting in values. These steps are considered essential in 'show that' questions, so candidates should be encouraged to show the substitutions clearly.
- (c) (i) The majority of answers were correct. A few answers contained power-of-ten errors.
- (ii) The calculation was straightforward for the well prepared candidates. The problem for a significant number of candidates was to realise that the electric force on the sphere was equal to the weight of the sphere.
- (iii) This was generally not well answered. The question asked for an explanation and there was insufficient detail given in the majority of answers. There was little reference to the electric force being greater than the weight or that the charge on the sphere had to be negative for the resultant force and hence the acceleration to be upwards.

Question 4

- (a) (i) A significant number of answers showed that the candidates had not read the question carefully. Reference was made to the arrangement of the molecules or the forces between molecules rather than the molecular motion. The molecular motion in solids was often described well but that for liquids was not as well described. In liquids a common description was that they were able to move more freely.
- (ii) Many answers were vague with reference being made to the molecules in a gas moving more freely than in a liquid.

- (b)(i) Many answers were spoilt by the straight section not being drawn with a ruler and looking very curved. Also some answers had a very small curved region compared with the linear section.
- (ii) This was generally well answered. Some answers were spoilt by a dramatic downwards kink at the very end of the straight line.
- (c) The similarity was generally given correctly. The difference was often not given with sufficient detail. Ductile materials were sometimes described as being able to be deformed past the elastic limit rather than having a plastic region. There was also confusion shown between the elastic limit, the limit of proportionality and the breaking point.

Question 5

- (a)(i) The working for this 'show that' question was generally not well presented. The two required values were often stated without any reference to any particular circuit. The majority of candidates obtained partial credit for the series combination. The answer for the parallel combination was often given as the following incorrect calculation: $1/\text{total resistance} = 1/X + 1/X = 2/X = X/2$. In 'show that' questions it is essential to conclude with a final statement. Often there was no comparison between the total resistance in the two circuits, or an inappropriate statement was made for the two circuits that $2X = X/2$ so $4X = X$.
- (ii) Candidates found this question difficult. Often the resistance for the two X resistors in parallel was compared with their resistance in series. Very few candidates referred to the internal resistance having an effect on the currents in the two circuits.
- (iii) A significant number of candidates were able to give the correct expression for the series circuit. There were some answers where the current was not identified or the sign of one of the terms was incorrect. The parallel circuit caused more difficulty and often two expressions of $X/2$ were included or the total resistance was given as $2/X$.
- (iv) Correct answers were obtained only by the very able candidates.
- (b) A majority of candidates gained partial credit for an expression for power. Only a minority went on to calculate the correct ratio. There were many basic errors of physics applied to the two circuits. Many thought that the current through each of the parallel resistors was 3.0A or that the potential difference across each lamp was 12V.
- (c) Very few candidates were able to explain that the resistance of a lamp is dependent on the potential difference across the lamp.

Question 6

- (a) The majority of candidates obtained credit for the similarity by referring to the transfer of energy. The answers for the difference that compared the direction of the vibrations of the particles to the direction of the energy transfer were often too imprecise. Comparisons with the 'wave motion' or the 'direction of the wave' were common vague descriptions.
- (b)(i) The answers were generally not of the required standard at AS Level. Many referred to constructive and destructive interference, waves being in phase or out of phase or crest meeting crest. A complete explanation required reference to the phase difference or path difference needed for maxima or minima. Very few candidates mentioned that the slits produce coherent waves and that this is a condition for the interference pattern to be observed.
- (ii) There were many correct answers. A minority made a power-of-ten error or could not rearrange an initially correct equation.
- (c) There were a minority of correct answers. Some referred to the wavelength of the ultra-violet being different or larger than that for light. Many did not provide an explanation, or simply stated that the spacing changed because the wavelength changed.

Question 7

- (a) (i)** The values for the numbers were generally correct.
- (ii)** The name used for the number represented by A and B was often given rather than the name of the particles.
- (b) (i)** A minority of candidates gave the correct form of energy.
- (ii)** Many candidates appeared not to be familiar with this type of calculation. These candidates were unable to convert the energy given in MeV to joules, and they would benefit from more practice using the electronvolt as a unit of energy.

PHYSICS

<p>Paper 9702/23 AS Structured Questions</p>
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General Comments

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There was no evidence that an adequately prepared candidate did not have sufficient time to complete the question paper.

Comments on Specific Questions

Question 1

- (a) (i) The great majority of candidates correctly named, or gave the abbreviations for, two base units.
- (b) (i) A few answers were left as Nm^{-2} rather than SI base units, but most were correctly derived with sufficient explanation.
- (ii) It was expected that a clear statement would be made to the effect that strain has no unit. Many acceptable units for strain were given as 'm/m'. Candidates should be discouraged from stating that the unit has a numerical value. That is, stating the unit as '1' or '0'.

Question 2

- (a) (i) Most answers correctly used the distance of 2.2 cm. A significant number of candidates gave the amplitude as 2.2 cm, rather than involve the Y-plate setting.
- (ii) The scale reading for the period is 3.8 cm. A large number of candidates did not give this result.
- (iii) There were comparatively few correct answers. The majority of candidates did not appear to appreciate that the uncertainty should be estimated by reference to the uncertainty in the measurement of the scale reading for the period. In this case, a reasonable estimate would be (3.8 ± 0.2) cm.

- (b) Of those candidates who did calculate the frequency and the actual uncertainty in the frequency, many found it difficult to give a correct statement. The uncertainty should be expressed to one significant figure with the frequency quoted to the same power-of-ten as the uncertainty.

Question 3

- (a) Most candidates did name three vectors, other than force. Answers such as 'weight' were not accepted because weight is a force, and force was excluded.
- (b)(i) With few exceptions, the correct answer of 70 N was quoted.
- (ii) In most answers, the angle was stated to be 90°. Explanations often did not include a statement relevant to equilibrium in both the horizontal and vertical directions.
- (iii) Both parts of this calculation were completed successfully by most candidates who appreciated the configuration of the forces. A small number used an incorrect trigonometric function for the angle.
- (c) It was expected that reference would be made to the fact that there is no vertical force to oppose the force Z. Some candidates discussed horizontal forces without mention of the situation in the vertical direction.

Question 4

- (a) Candidates should appreciate that, where momentum is conserved, there can be forces acting on the system. The crucial point is that there should be no resultant force acting on the system.
- (b)(i) This calculation was well done. A small minority did not convert the masses to kg.
- (ii) Again, most answers were correct. Some candidates did not use the answer obtained in (i) but instead recalculated the initial total momentum.
- (iii) Although the majority of answers were correct, some candidates calculated the total final kinetic energy rather than the total initial kinetic energy. Others incorrectly summed the masses and summed the speeds before substituting into the expression for kinetic energy.
- (c) Most answers were given by reference to kinetic energy, rather than relative speeds of approach and separation. A common error was to refer to kinetic energy without specifying total kinetic energy.
- (d) Very few candidates made any reference to the time of collision. With few exceptions, equal and opposite forces were discussed but it was thought that the forces alone would give rise to equal but opposite changes in momentum. A complete explanation should refer to change in momentum as being related to the product $F\Delta t$ and that Δt is the same for both spheres.

Question 5

There were some good responses. Others considered the situation only for water. A common problem with wording was to state that boiling occurs at a 'constant' temperature, rather than at a specific temperature.

Question 6

- (a) Candidates need to be able to recall relevant formulae for areas and volumes. Many incorrect attempts were based on incorrect substitutions for the cross-sectional area. Candidates should be encouraged to show clearly any substitutions so that arithmetical errors can be avoided.
- (b)(i) Most candidates did quote a formula relevant to the expression $V = IR$. However, very few then calculated the correct value for the current. A common incorrect answer was found by dividing the e.m.f. of the cell by its internal resistance.
- (ii) There were few correct answers, based on the product of the current determined in (i) and the resistance of the wire.

(iii) For a sensible answer to be obtained, the p.d. across the wire must be greater than the e.m.f. of cell Y. Frequently, this was not the case and this led to unphysical values of L .

(c) Question discounted.

Question 7

(a) (i) In many answers, reference was made to transfer of energy. When describing a transverse wave, candidates should be advised to refer to not only the direction of vibration of particles but also the direction of travel, or energy transfer, of the wave. It is not sufficient to refer to 'the direction of the wave'.

(ii) Reference should be made to the number of oscillations per unit time. In some cases the ratio was not made clear or the definition was given in terms of the second.

(b) There were some correct responses but often candidates found it difficult to determine a phase difference. Some quoted a single point, rather than two points.

(c) Most answers were correct. The most common error was omitting to convert the wavelength to the unit of metres.

(d) This was answered correctly by most candidates. Some answers were the reciprocal of the correct result. Where explanation of the working was not provided, then it was not possible to distinguish between an arithmetical error and an error in the physics of the situation. Candidates should be encouraged always to show their working, so that they may be awarded partial credit for correct physics when there is a subsequent arithmetical error.

PHYSICS

Paper 9702/31
Advanced Practical Skills 1

Key Messages

- Candidates should take care in using appropriate precision for all of their measurements. The correct precision is principally determined by the precision of the measuring instrument being used. It is important not to record answers with insufficient precision, and similarly important not to add extra zeros to recorded values to give a false impression of greater precision.
- If a candidate restricts measurements to a small part of the available range, the scatter of points plotted on a graph grid is increased. This can make it more difficult to identify a trend and harder to choose a line of best fit. Candidates should be encouraged to use a range that is as wide as possible when taking measurements.
- Many candidates may gain more credit by being alert to units. Measurements should always be recorded with units, and most calculated quantities also require units in order to be valid. The omission of units is a common cause of lost credit.
- To score highly on **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. General points such as “avoid parallax error” or “use more precise measuring instruments” will not usually gain credit without further detail.

General Comments

The general standard of the work done by the candidates was good, with many excellent scripts.

The majority of Centres had no problem in providing the equipment required for use by candidates. Any deviation between the requested equipment and that provided to the candidates should be written down in the Supervisor’s Report, and this report must be sent with the scripts to Cambridge so that the Examiners can take this into consideration during the marking period. Experiments are designed with the view that Centres will have the apparatus as outlined in the syllabus available for use. Any help given to a candidate should be noted on the Supervisor’s Report. Supervisors are reminded that under **no circumstances** should help be given with the recording of results, graphical work or analysis.

Centres are reminded of the importance of following the Confidential Instructions exactly, using the materials and equipment specified. No ‘extra’ equipment should be available to the candidates. In some cases this may disadvantage candidates.

Candidates did not seem to be short of time. Most candidates were confident in the generation and handling of data but could improve by giving more thought to the critical evaluation of experiments.

Comments on Specific Questions

Question 1

In this question, candidates were asked to investigate the motion of a system of masses.

Successful collection of data

- (b) Many candidates were able to take at least two values of $10T$ to find the average T . Some candidates repeated a single swing 10 times and did not gain credit. Other candidates were not

awarded full credit because they recorded just one time for 10 oscillations or, having taken the time for 10 oscillations, did not divide this value by 10 to get the time for one oscillation. Some divided the time taken by a different number (e.g. 15) even though the candidate stated that 10 swings were taken. A few candidates misread the stopwatch, recording times much less than 1 second or took the time for half of the oscillation instead. Some candidates omitted the unit.

- (d) Most candidates were able to collect six sets of values of B , C and T without any assistance from the Supervisor. Several candidates lost credit because their results did not show the correct trend. If candidates choose to record more than the prescribed six sets of values, it is important to note that all the extra points should be plotted on the graph to avoid losing credit for the plotting of points.

Range and distribution of values

- (d) Many candidates did not extend their range of B and C to cover the whole range of the number of masses supplied. It was common for candidates to start with $B = 0$ or 1, increasing this by one until $B = 5$ or 6 without extending to $B = 7$ or 8.

Quality of data

- (e) (i) Most candidates were awarded credit for the quality of their data. Of those who were not, most had obtained an incorrect trend on their graph, or had calculated values of T/B , T^2B or TB rather than T^2/B .

Table

- (d) Most candidates were awarded the mark for using the correct column headings in their tables, giving both the quantity recorded and suitable units for each quantity, with the two separated by a solidus or with the units in brackets. No units were expected for C/B . Some candidates omitted units for T^2/B , omitted the separating mark or recorded the units for T^2/B as s^2/kg or s^{-2} rather than s^2 .

Many candidates recorded their raw values for t to the nearest 0.1 s or 0.01 s, gaining credit. Some candidates incorrectly stated their raw t values to the nearest second, presented trailing zeros to a greater precision than 0.01 s or misread the stopwatch to obtain values of t that were much less than 1 s.

Many candidates calculated values for T^2/B correctly, though a few rounded their answers incorrectly. Some candidates instead calculated TB or T^2B .

Many recorded their calculated values for T^2/B to an appropriate number of significant figures. Some candidates recorded their values concentrating on the same number of decimal places instead of looking at the number of significant figures and keeping these consistent with the raw readings.

Graph

- (e) (i) Candidates were required to plot a graph of T^2/B against C/B . Most candidates gained credit for drawing appropriate axes, with labels and sensible scales.

A few candidates chose the smallest and largest tabulated values for T^2/B as the two values at either end of the scale on the graph paper, interpolating the other points between these two extremes. This method should be discouraged as it can cause candidates to lose credit in several places. As well as losing credit for the axes, these candidates often lost credit for incorrect plotting of points or incorrect read-offs when calculating the gradient or intercept. The resulting scales are very difficult to use to plot or read off intermediate values.

Many candidates gained credit for plotting their tabulated readings correctly. If a point seems anomalous, candidates should repeat the measurement to check that an error has not been made in recording the value. If such a point is ignored in assessing the straight line of best fit, the anomalous point should be labelled clearly, e.g. by circling the point. The pencil points or crosses should be clear. Some candidates drew very faint points that were difficult to see, or had rubbed out correctly plotted points when redrawing the line of best fit.

Most candidates plotted their points on the graph paper with great care; others needed to draw the plotted points so that the diameters of the points were equal to, or less than, half a small square (a small pencil cross is recommended). Some candidates can improve by plotting the points more accurately and by ensuring they use a sharp pencil and a straight ruler.

- (e) (ii)** Many candidates were able to draw carefully considered lines of best fit, but some weaker candidates joined the first and last points on the graph regardless of the distribution of the other points. There should always be a balanced distribution of points either side of the line along the entire length.

Interpretation of graph

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

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

Many candidates correctly substituted a read-off into $y = mx + c$ to determine the y -intercept. Others needed to check that the point chosen was actually on the line of best fit and not just a point from the table.

Drawing conclusions

- (f)** Most candidates recognised that F was equal to the value of the gradient and G was equal to the value of the intercept calculated in **(e)(iii)**. A few candidates tried to calculate F and G by first substituting values into the given equation and then solving the simultaneous equations, or by repeating the calculations already completed in **(e)(iii)**. No credit is given for this as the question specifically asks for the answers in **(e)(iii)** to be used to determine F and G .

The majority of candidates recorded the correct units for F and G (both s^2). Others stated incorrect units or omitted the units for F and G .

Question 2

In this question, candidates were required to investigate how the number of turns of wire around a rod depends on the diameter of the wire.

Successful collection of data

- (a) (i)** Most candidates recorded a value for d with unit successfully and in the appropriate range.
- (ii)** Some candidates recorded a value for d successfully, using the micrometer to record a value to the nearest 0.01 mm (or 0.001 mm if using a digital micrometer) and in the range 0.14 to 0.16 mm. Others either misread the micrometer (for example, giving values such as 0.15 cm) or recorded their values with insufficient precision (for example, 0.2 mm). When using a micrometer, a precision of either ± 0.01 mm or ± 0.001 mm is expected.
- (b)(ii)** Most candidates correctly recorded an integer value of the number of turns and represented part of the remaining turn as a fraction or a decimal.
- (c)** Most candidates recorded second values for d and $(n + t)$.

Quality of data

- (c) Most candidates recorded values for $(n + t)$ which were smaller for the thicker wire.

Display of calculation and reasoning

- (a)(iii) Most candidates correctly calculated $(D + d/2)$.
- (d)(i) Many of the candidates were able to calculate k for the two sets of data, showing their working clearly. Some candidates incorrectly rearranged the equation when calculating k .
- (ii) Some candidates justified the number of significant figures they had given for the value of k , giving reference to the number used in the raw values of D , d and $(n + t)$. Reference to just the 'raw data' is not sufficient to be awarded credit.

Drawing conclusions

- (d)(iii) Most candidates calculated the percentage difference between their two values of k , and then tested it against a specified percentage uncertainty, either taken from (b)(iii) or estimated themselves. Some candidates gave answers such as "the difference in the two k values is very large/quite small" which is insufficient to be awarded credit. A numerical percentage comparison is required.

Estimating uncertainties

- (b)(iii) Most candidates were familiar with the equation for calculating percentage uncertainty, though some made too small an estimate of the absolute uncertainty in the value of $(n + t)$, typically 1 mm, or too large an estimate (over $\frac{1}{4}$ of a turn).

Evaluation

- (e) Many candidates recognised that two sets of data were insufficient to draw a valid conclusion. Several candidates successfully identified the judgement of the fraction of the remaining turn as a possible source of error, and also stated that the coil of wire sprang away from the rod. Some described how the length was not exactly 50.0 cm with a reason, e.g. kinks in the wire, and gave appropriate methods to secure the wire. Valid improvements included taking more readings (for different diameters) and then plotting a suitable graph to test the suggested relationship.

Some candidates suggested the use of 'better' equipment without describing how such equipment would be used. Credit is not given for suggestions that could be carried out in the original experiment, such as repeating measurements or avoiding parallax errors by looking at eye level. General answers such as 'systematic error' or 'use an assistant' are not given credit.

The key to this section is for candidates to identify genuine problems associated with setting up this experiment and in obtaining readings. Candidates are encouraged to suggest detailed practical solutions that either improve technique or give more reliable data.

PHYSICS

Paper 9702/33
Advanced Practical Skills 1

Key Messages

- Candidates should take care in using appropriate precision for all of their measurements. The correct precision is principally determined by the precision of the measuring instrument being used. It is important not to record answers with insufficient precision, and similarly important not to add extra zeros to recorded values to give a false impression of greater precision.
- If a candidate restricts measurements to a small part of the available range, the scatter of points plotted on a graph grid is increased. This can make it more difficult to identify a trend and harder to choose a line of best fit. Candidates should be encouraged to use a range that is as wide as possible when taking measurements.
- Many candidates may gain more credit by being alert to units. Measurements should always be recorded with units, and most calculated quantities also require units in order to be valid. The omission of units is a common cause of lost credit.
- To score highly on **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. General points such as “avoid parallax error” or “use more precise measuring instruments” will not usually gain credit without further detail.

General Comments

The general standard of the work done by the candidates was good, with many excellent scripts.

The majority of Centres had no problem in providing the equipment required for use by candidates. Any deviation between the requested equipment and that provided to the candidates should be written down in the Supervisor’s Report, and this report must be sent with the scripts to Cambridge so that the Examiners can take this into consideration during the marking period. Experiments are designed with the view that Centres will have the apparatus as outlined in the syllabus available for use. Any help given to a candidate should be noted on the Supervisor’s Report. Supervisors are reminded that under **no circumstances** should help be given with the recording of results, graphical work or analysis.

Centres are reminded of the importance of following the Confidential Instructions exactly, using the materials and equipment specified. No ‘extra’ equipment should be available to the candidates. In some cases this may disadvantage candidates.

Candidates did not seem to be short of time. Most candidates were confident in the generation and handling of data but could improve by giving more thought to the critical evaluation of experiments.

Comments on Specific Questions

Question 1

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

Successful collection of data

- (c) Many candidates were able to take at least two values of $10T$ to find the average T . Some candidates repeated a single swing 10 times and did not gain credit. Other candidates were not

awarded full credit because they recorded just one time for 10 oscillations or, having taken the time for 10 oscillations, did not divide this value by 10 to get the time for one oscillation. Some divided the time taken by a different number (e.g. 15) even though the candidate stated that 10 swings were taken. A few candidates misread the stopwatch, recording times much less than 1 second or took the time for half of the oscillation instead. Some candidates omitted the unit.

- (d) Most candidates were able to collect six sets of values of L and T without any assistance from the Supervisor. Several candidates lost credit as their results did not show the correct trend. If candidates choose to record more than the prescribed six sets of values, it is important to note that all the extra points should be plotted on the graph to avoid losing credit for the plotting of points.

Range and distribution of values

- (d) Many candidates did not extend their range of L values used to cover at least 30.0 cm along the length of the rod. Many candidates used a range of less than 10.0 cm or, in some cases, less than 5.0 cm. Candidates should be encouraged to use as much of L as possible and this is good experimental practice.

Quality of data

- (e) (i) Most candidates were awarded credit for the quality of their data. Of those who were not, most had obtained an incorrect trend on their graph, or had calculated values of T^2/L rather than T^2L .

Table

- (d) Most candidates were awarded credit for using the correct column headings in their tables, giving both the quantity recorded and suitable units for each quantity, with the two separated by a solidus or with the units in brackets. Some candidates omitted the units for T^2L , omitted the separating mark or recorded the units for T^2L as s^2/m or m/s rather than s^2m .

Many candidates recorded their raw values for L to the nearest 0.1 cm, gaining credit. Some candidates incorrectly stated their L values to the nearest cm or presented trailing zeros to a greater precision than 1 mm. The measuring instrument provided (a metre rule) can be read to the nearest mm. A few candidates stated inconsistent units (e.g. 50 m).

Many candidates calculated values for T^2L correctly, though a few rounded their answers incorrectly and lost credit. Some candidates instead calculated TL , L^2T or L^2T^2 .

Recording of calculated values of T^2L to an appropriate number of significant figures was well done. Some candidates recorded their values concentrating on the same number of decimal places instead of looking at the number of significant figures and keeping these consistent with the raw readings.

Graph

- (e) (i) Candidates were required to plot a graph of T^2L against L^2 . Most candidates gained credit for drawing appropriate axes, with labels and sensible scales.

A few candidates chose the smallest and largest tabulated values for T^2L as the two values at either end of the scale on the graph paper, interpolating the other points between these two extremes. This method should be discouraged as it can cause candidates to lose credit in several places. As well as losing credit for the axes, these candidates often lost credit for incorrect plotting of points or incorrect read-offs when calculating the gradient or intercept. The resulting scales are very difficult to use to plot or read off intermediate values.

Many candidates gained credit for plotting their tabulated readings correctly. If a point seems anomalous, candidates should repeat the measurement to check that an error has not been made in recording the value. If such a point is ignored in assessing the straight line of best fit, the anomalous point should be labelled clearly, e.g. by circling the point. The pencil points or crosses should be clear. Some candidates drew very faint points that were difficult to see, or had rubbed out correctly plotted points when redrawing the line of best fit.

Most candidates plotted their points on the graph paper with great care; others needed to draw the plotted points so that the diameters of the points were equal to, or less than, half a small square (a small pencil cross is recommended). Some candidates can improve by plotting the points more accurately and by ensuring they use a sharp pencil and a straight ruler.

- (e)(ii)** Many candidates were able to draw carefully considered lines of best fit, but some weaker candidates joined the first and last points on the graph regardless of the distribution of the other points. There should always be a balanced distribution of points either side of the line along the entire length.

Interpretation of graph

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

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

Many candidates correctly substituted a read-off into $y = mx + c$ to determine the y -intercept. Others needed to check that the point chosen was actually on the line of best fit and not just a point from the table.

Drawing conclusions

- (f)** Most candidates recognised that A was equal to the value of the gradient and B was equal to the value of the intercept calculated in **(e)(iii)**. A few candidates tried to calculate A and B by first substituting values into the given equation and then solving the simultaneous equations, or by repeating the calculations already completed in **(e)(iii)**. No credit is given for this as the question specifically asks for the answers in **(e)(iii)** to be used to determine A and B .

The majority of candidates recorded the units for A ($\text{s}^2 \text{m}^{-1}$) and B ($\text{s}^2 \text{m}$) correctly. Others stated incorrect units or omitted the units for A and B .

Question 2

In this question, candidates were required to investigate how the rebound height of a ball from an inclined board depends on the angle of the board.

Successful collection of data

- (a)(ii)** Many candidates recorded a value for h_2 in the appropriate range with an appropriate unit. Some candidates omitted the unit or did not record repeat readings, despite in some cases referring later to this being a difficult reading to take.
- (b)(ii)** Most candidates recorded a sensible value of θ in range with an appropriate unit. Some candidates incorrectly showed the precision by adding too many zeros (e.g. 11.00°) or gave unachievable precision considering the measuring device used (e.g. 11.3°).
- (c)(iii)** Most candidates recorded a value of h with a consistent unit. Some candidates omitted the unit.
- (d)(i)** Most candidates recorded a second value for θ .
- (ii)** Most candidates recorded a second value for h .

Quality of data

- (d)(ii) Most candidates recorded values for h which were smaller for the larger angle.

Display of calculation and reasoning

- (b)(iii) Many candidates correctly calculated $\cos^2 2\theta$. A minority of candidates did not use their calculators correctly and stated values over 100.
- (iv) Some of the candidates justified the number of significant figures they had given for the value of $\cos^2 2\theta$ by reference to the number of significant figures used in the raw value of the angle. Reference to just the 'raw data' is not sufficient here and did not gain credit.
- (e)(i) The majority of candidates were able to calculate k for the two sets of data, showing their working clearly. Some candidates incorrectly worked out new values of q for each experiment or incorrectly rearranged the equation when calculating k .

Drawing conclusions

- (e)(ii) Most candidates calculated the percentage difference between their two values of k , and then tested it against a specified percentage uncertainty, either taken from (c)(iv) or estimated themselves. Some candidates gave answers such as 'the difference in the two k values is very large/quite small' which is insufficient to be awarded credit. A numerical percentage comparison is required.

Estimating uncertainties

- (c)(iv) Most candidates were familiar with the equation for calculating percentage uncertainty, though some made too small an estimate of the absolute uncertainty in the value of h , typically the smallest division on the ruler, 1 mm.

Evaluation

- (f) Many candidates recognised that two sets of data were insufficient to draw a valid conclusion. It was common for candidates to identify the measurement of h as a possible source of error, but without explaining why. A detailed answer would state that there was no lower horizontal reference line or that the ball stops at the maximum height for a short time (not that the ball travels too fast). Many candidates stated that parallax error was a problem or that it was difficult to keep the ruler vertical, but did not make reference to the reading this difficulty affects. Many candidates stated that the thickness of the board prevented reading the angle accurately, or that there was a gap between the 0° line and the base of the protractor, but the protractor could be moved along the horizontal to make an accurate reading.

Valid improvements included taking more readings (for different angles) and then plotting a suitable graph to test the suggested relationship. Many improvements were not awarded credit because they were not specific enough, e.g. use of cameras without any reference to some scale against which to judge h .

Many candidates suggested the use of 'better' equipment or computers/data loggers/sensors without describing how such equipment would be used. Credit is not given for suggestions that could be carried out in the original experiment, such as repeating measurements or avoiding parallax errors by looking at eye level. General answers such as 'systematic error' or 'use an assistant' are not given credit.

The key to this section is for candidates to identify genuine problems associated with setting up this experiment and in obtaining readings. Candidates are encouraged to suggest detailed practical solutions that either improve technique or give more reliable data.

PHYSICS

Paper 9702/34
Advanced Practical Skills 2

Key Messages

- Candidates should take care in using appropriate precision for all of their measurements. The correct precision is principally determined by the precision of the measuring instrument being used. It is important not to record answers with insufficient precision, and similarly important not to add extra zeros to recorded values to give a false impression of greater precision.
- If a candidate restricts measurements to a small part of the available range, the scatter of points plotted on a graph grid is increased. This can make it more difficult to identify a trend and harder to choose a line of best fit. Candidates should be encouraged to use a range that is as wide as possible when taking measurements.
- Many candidates may gain more credit by being alert to units. Measurements should always be recorded with units, and most calculated quantities also require units in order to be valid. The omission of units is a common cause of lost credit.
- To score highly on **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. General points such as “avoid parallax error” or “use more precise measuring instruments” will not usually gain credit without further detail.

General Comments

Nearly all candidates had time to complete both questions, and the results and analysis were generally clearly presented. In many cases Centres had prepared their candidates well after referring to mark schemes from previous papers. These candidates knew what was expected in the production and analysis of graphs and there were some very good marks. The standard shown in calculations was very good, and usually included accurate rounding of answers. Very few candidates asked for help with using the apparatus.

Centres reported few problems with providing the necessary apparatus for the two questions. Candidates from some Centres reported in **Question 2** that the nail used as a pivot was only loosely held in the boss. This problem drew their attention away from the measurements themselves when they were discussing sources of uncertainty. Centres should ensure that apparatus assembled in advance of the examination is securely fastened together.

Comments on Specific Questions

Question 1

In this question, candidates were asked to investigate the refraction of light by a transparent block.

Successful collection of data

- (b)(ii) This initial value of p was in the expected range for almost every candidate.
- (c)(iii) The initial value of q should have been greater than p as emerging light is refracted away from the normal, and this was usually the case.

- (d) Nearly every candidate recorded six or more different values for p and q , and in most cases the q values showed the expected trend (increasing as p increased).

Range and distribution of values

- (d) The apparatus allowed for p to both increase and decrease from the starting value of approximately 4.5 cm, and the best candidates used values from both of these directions.

Table

- (d) Most tables were neat and well-organised. Stronger candidates included suitable units where appropriate in the table headings, with clear separation from their quantity. In a few cases the quantity q/p was mistakenly given a unit, usually cm.

Stronger candidates correctly recorded all their values of q and p to the nearest mm. This resulted in values with two significant figures, e.g. 3.6 cm.

Calculations were nearly always accurate, with incorrect rounding only in very few cases.

Where the data used in the calculation had two significant figures, the calculated value of q/p could have either two or three s.f. The values of q/p were all close together, so using only two s.f. for calculated values gave some identical q/p values in their table (e.g. 6.0/4.6 and 9.1/6.9 both gave q/p equal to 1.3).

Graph

- (e) (i) Good graphs had simple, clearly labelled scales with all points from the table clearly and accurately plotted using small crosses. Where dots were used they were sometimes too large (over 1 mm in diameter), so that the intended position was not clear.

There were a few cases of awkward scales, the most common error being one large square representing a value of 0.03 (making plotting and reading more difficult, and mistakes much more likely). Some scales were very compressed, so that only a small part of the grid was used.

In this experiment the transparent block was removed and then replaced between each set of readings. When this was done carefully and accurate readings were taken, the graph showed some scatter about a linear trend with negative gradient. Candidates who used a limited range of p values, or used only 2 s.f. when plotting points, often found that their scatter was wide enough to mask the trend.

- (ii) Before drawing their line of best fit, many candidates sensibly circled an outlying point to show that it was anomalous and they were ignoring it. The best graphs had a line that followed the general trend and was also as close as possible to all of the points.

Interpretation of graph

- (e) (iii) Nearly all candidates knew how to calculate the gradient of their line using coordinates from two points, though in a few cases the points were too close together (they should be separated by at least half the length of the candidate's line). Most candidates whose $1/p$ axis started at zero read the intercept directly from their graph. Where the $1/p$ axis did not start at zero, weaker candidates often made the mistake of reading the intercept from the q/p axis instead of calculating a correct value.

Drawing conclusions

- (f) Many candidates inspected the equation and saw that the value of the constant a had to be calculated using both gradient and intercept values. Stronger candidates also realised that a had the unit cm and constant b had no unit.

Quality of data

- (f) The quality of results was judged from the candidate's value for the constant b , as this represents the refractive index of the transparent block material. Most candidates whose graph had a negative trend were awarded credit.

Question 2

In this question, candidates were required to hammer a rod into a container of rice to investigate the relationship between surface area and the resisting frictional force.

Successful collection of data

- (a) Candidates were required to use calipers to measure the thickness d of the pencil and state the value in cm. Most candidates did this successfully, although a few had power-of-ten errors (e.g. 0.071 cm or 7.1 cm instead of 0.71 cm).

Nearly all gave a value for x in the expected range and a value for l to the required precision.

- (d) All candidates recorded a value for the number n of hits. Relatively few candidates investigated the possible variation in n by repeating the test.
- (e) Nearly all candidates repeated the experiment using the second pencil with a different area of contact with the rice, although a small number used pencil P again.

Quality of data

- (e) In most cases the expected result was found, i.e. more hits were needed when the area of contact was greater.

Display of calculation and reasoning

- (c) The calculation of the area A was done well, with very few omitting a correct unit or misinterpreting the square root symbol.
- (f) (i) Most candidates successfully calculated two values for the constant k . Only a few candidates made mistakes when rearranging the equation or when transferring values into their formula.
- (ii) Although the majority knew that the number of significant figures given for k should be based on the raw data used in its calculation, most candidates listed the calculated value A as raw data rather than the measurements d and l from which A was determined.

Drawing conclusions

- (f) (iii) There were many good answers here, with clearly reasoned discussion based on the two k values. Some looked at the relative difference between the two values (i.e. the percentage difference) and compared it with a reasonable percentage variation for this experiment. Some applied their chosen percentage variation to each k value and then looked for overlap. Weaker answers only discussed whether the difference between k values was 'large' or 'small'.

Estimating uncertainties

- (b) The measurement of l was from the end of the sharpened part of the pencil. The boundary between the conical and parallel sections was ragged and not well defined, so there was an uncertainty of between 2 and 5 mm in this starting point. Very few candidates took this into account and simply used the precision of their measuring instrument (ruler or calipers) as the uncertainty.

Evaluation

(g) Most candidates made a good attempt at evaluating the experiment.

Many were credited for the general comment that the validity of the equation couldn't be judged from only two values of k , and more tests were needed using different contact areas.

Many also identified that it was difficult to ensure that the drop height was the same each time. The solution commonly offered was to clamp a scale behind the wooden strip, but only a small number of candidates suggested the better method of clamping a stop above the strip so that it was always raised to the same position.

The method of checking that the strip was initially horizontal was often credited, although some did not fully describe the use a metre rule to compare the two end heights above the bench.

Another major problem was the tilting of the pencil away from the vertical as it was hammered into the rice. Although many candidates described this difficulty, very few described a workable guiding method to improve it.

Some problems were offered by many candidates but were not significant enough to be credited, e.g. 'it was difficult to release the strip without applying a force'. Some solutions were not fully described, e.g. 'use a set square to ensure the strip is horizontal'.

PHYSICS

Paper 9702/35
Advanced Practical Skills 1

Key Messages

- Candidates should take care in using appropriate precision for all of their measurements. The correct precision is principally determined by the precision of the measuring instrument being used. It is important not to record answers with insufficient precision, and similarly important not to add extra zeros to recorded values to give a false impression of greater precision.
- If a candidate restricts measurements to a small part of the available range, the scatter of points plotted on a graph grid is increased. This can make it more difficult to identify a trend and harder to choose a line of best fit. Candidates should be encouraged to use a range that is as wide as possible when taking measurements.
- Many candidates may gain more credit by being alert to units. Measurements should always be recorded with units, and most calculated quantities also require units in order to be valid. The omission of units is a common cause of lost credit.
- To score highly on **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. General points such as “avoid parallax error” or “use more precise measuring instruments” will not usually gain credit without further detail.

General Comments

The majority of Centres had no problem in providing the equipment required for use by candidates, although though a few Centres provided cups for **Question 2** that were different from those described in the Confidential Instructions. Any deviation between the requested equipment and that provided to the candidates should be written down in the Supervisor’s Report, and this report must be sent with the scripts to Cambridge so that the Examiners can take this into consideration during the marking period. Experiments are designed with the view that Centres will have the apparatus as outlined in the syllabus available for use. Any help given to a candidate should be noted on the Supervisor’s Report. Supervisors are reminded that under **no circumstances** should help be given with the recording of results, graphical work or analysis.

Centres are reminded of the importance of following the Confidential Instructions exactly, using the materials and equipment specified. No ‘extra’ equipment should be available to the candidates. In some cases this may disadvantage candidates.

Candidates did not seem to be short of time. Most candidates were confident in the generation and handling of data but could improve by giving more thought to the critical evaluation of experiments.

Comments on Specific Questions

Question 1

In this question, candidates investigated the motion of masses suspended from springs.

Successful collection of data

- (a) (ii) Almost all candidates recorded correctly a value for $(m - P)$, normally 50g. A few candidates omitted units and were not awarded credit.

- (b)(ii)** Some candidates misunderstood the instruction to measure the time t between the two oscillators being in phase for the first time and being in phase again for the sixth time. Using the equipment specified in the Confidential Instructions, the time t should have been 30 s – 40 s, though there were several answers less than 10 s.

Several candidates appeared to have recorded instead the time for just 5 or 6 oscillations of one of the oscillators, or the time taken for the two oscillators to go from being in phase to out of phase and back in phase again just once. A few candidates misread the stopwatch, recording times much less than 1 second.

- (c)** Most candidates were able to collect six sets of values of m and t without any assistance from the Supervisor. Several candidates lost credit as their results did not show the correct trend.

If candidates choose to record more than the prescribed six sets of values, it is important to note that all the extra points should be plotted on the graph to avoid losing credit for the plotting of points.

Range and distribution of values

- (c)** Using the masses specified in the Confidential Instructions, the maximum possible value for m was 380 g. Candidates were awarded credit for an appropriate range if they used a mass m equal to 360 g or greater. The majority of candidates did this successfully. A few candidates lost credit for using values for m less than 250 g as the instructions specifically ask candidates to increase m from the initial value of 250 g.

Quality of data

- (d)(i)** Most candidates were awarded credit for the quality of their data. Of those who were not, most had obtained an incorrect (negative) trend on their graph, or had calculated values of $1/t$ rather than $1/t^2$.

Table

- (c)** Most candidates were awarded credit for using the correct column headings in their tables, giving both the quantity recorded and suitable units for each quantity, with the two separated by a solidus or with the units in brackets. Some candidates either omitted the units for $1/t^2$ or recorded the units for $1/t^2$ as s^2 rather than s^{-2} .

Most candidates recorded their raw values for t to either the nearest 0.1 s or 0.01 s.

Most recorded their calculated values for $1/t^2$ to an appropriate number of significant figures. It is recommended that candidates use standard form whenever possible, particularly when recording very small values. For example, 3.46×10^{-3} s is preferable to 0.00346 s. In this experiment, values for t of 40.0 s, for example, gave a value for $1/t^2$ of 6.25×10^{-4} s.

Most candidates calculated values for $1/t^2$ correctly, though a few rounded their answers incorrectly and were not awarded credit.

Graph

- (d)(i)** Candidates were required to plot a graph of $1/t^2$ against $(m - P)$. Most candidates gained credit for drawing appropriate axes, with labels and sensible scales.

A few candidates chose the smallest and largest tabulated values for T^2L as the two values at either end of the scale on the graph paper, interpolating the other points between these two extremes. This method should be discouraged as it can cause candidates to lose credit in several places. As well as losing credit for the axes, these candidates often lost credit for incorrect plotting of points or incorrect read-offs when calculating the gradient or intercept. The resulting scales are very difficult to use to plot or read off intermediate values.

Many candidates gained credit for plotting their tabulated readings correctly. If a point seems anomalous, candidates should repeat the measurement to check that an error has not been made in recording the value. If such a point is ignored in assessing the straight line of best fit, the

anomalous point should be labelled clearly, e.g. by circling the point. The pencil points or crosses should be clear. Some candidates drew very faint points that were difficult to see, or had rubbed out correctly plotted points when redrawing the line of best fit.

Most candidates plotted their points on the graph paper with great care; others needed to draw the plotted points so that the diameters of the points were equal to, or less than, half a small square (a small pencil cross is recommended). Some candidates can improve by plotting the points more accurately and by ensuring they use a sharp pencil and a straight ruler.

- (d)(ii)** Many candidates were able to draw carefully considered lines of best fit, but some weaker candidates joined the first and last points on the graph regardless of the distribution of the other points. There should always be a balanced distribution of points either side of the line along the entire length.

Interpretation of graph

- (d)(iii)** Many candidates used a suitably large triangle to calculate the gradient, gaining credit for correct read-offs, and substituted into $\Delta y/\Delta x$ to find the gradient. Other candidates needed to check that the read-offs used were within half a small square of the line of best fit, show clearly the substitution into $\Delta y/\Delta x$ (not $\Delta x/\Delta y$), and check that the triangle for calculating the gradient is large enough (the hypotenuse should be greater than half the length of the line drawn).

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

Many candidates correctly substituted a read-off into $y = mx + c$ to determine the y -intercept. Others needed to check that the point chosen was actually on the line of best fit and not just a point from the table.

Drawing conclusions

- (e)** Most candidates recognised that U was equal to the value of the gradient and V was equal to the value of the intercept calculated in **(d)(iii)**. A few candidates tried to calculate U and V by first substituting values into the given equation and then solving the simultaneous equations, or by repeating the calculations already completed in **(d)(iii)**. No credit is given for this as the question specifically asks for the answers in **(d)(iii)** to be used to determine U and V .

The majority of candidates recorded the correct units for U ($\text{s}^{-2}\text{kg}^{-1}$ or $\text{s}^{-2}\text{g}^{-1}$) and V (s^{-2}) correctly. Others had units such as s^2g^{-1} or s^{-2}g , or omitted the units for U and V completely.

Question 2

In this question, candidates were required to investigate the motion of a plastic cup in water.

Successful collection of data

- (a)** Some candidates recorded a value for x successfully, using the micrometer to record a value to the nearest 0.01 mm (or 0.001 mm if using a digital micrometer) and in the range 0.10 to 0.30 mm. Others either misread the micrometer (for example, giving values such as 0.10 cm) or recorded their values with insufficient precision (for example, 0.2 mm). When using a micrometer, a precision of either ± 0.01 mm or ± 0.001 mm is expected.

A wide variety of plastic cups were used. Examiners were able to make an allowance for this provided specimen values were recorded by the Supervisor in the Supervisor's Report. A few Centres used expanded polystyrene cups that were both thicker and lighter than the cups specified in the Confidential Instructions, and these failed to sink.

- (b)(i)** The majority of candidates recorded a value for A by first drawing the outline of the hole in the cup on the grid and then 'counting squares' to obtain the area. A few candidates calculated the area by measuring the approximate diameter of the hole and then using $\pi d^2/4$ (i.e. not using the grid). This method was not awarded credit as it was inaccurate and contrary to the instructions.

(c)(iii) Most candidates recorded a sensible value for the time T taken for the cup to fall from the top to the bottom of the bucket (a wide range of times were credited). Some candidates needed to include units in their answer, or misread the minutes on the stopwatch as seconds, recording answers much less than 1.0 s.

(d) Most candidates recorded a second value for A .

Some candidates repeated their measurements when recording a value for T , in either **(c)(iii)** or **(d)**. Candidates should be encouraged to repeat any measurement that could be subject to variation when repeated.

Quality of data

(d) Most candidates recorded values for T which were smaller for the cup with the larger hole.

Display of calculation and reasoning

(b)(iii) Almost all candidates were able to calculate V correctly, usually converting x into cm or both x and A into m and m^2 respectively before multiplying x and A together. A few candidates converted cm^2 into mm^2 incorrectly (by multiplying by 10 rather than 100), and some converted cm^2 into m^2 incorrectly (by multiplying by 100 rather than 10^4).

Most candidates recorded units for V that were consistent with their calculation (either mm^3 , cm^3 or m^3), though some had multiplied the area in cm^2 by the thickness x in mm so could not give a unit consistent with their answer. Others lost credit because they recorded the volume in a dimensionally incorrect unit, e.g. mm or cm^2 .

(iv) The majority of candidates justified the significant figures they had given for the value of V correctly by linking, explicitly, the significant figures for V to the raw data A and x . Candidates who calculated the area using $\pi d^2/4$ would have needed to link the significant figures in V to the significant figures in x and the diameter d (or radius r). Reference to just the 'raw data' is not sufficient here and did not gain credit.

(e)(i) The great majority of candidates were able to calculate k for the two sets of data, showing their working clearly. A few candidates calculated V/T^2 or T^2/V and were not given credit.

Drawing conclusions

(e)(ii) Most candidates calculated the percentage difference between their two values of k , and then tested it against a specified percentage uncertainty, either taken from **(b)(ii)** or estimated themselves (usually 20%). Some candidates gave answers such as "the difference in the two k values is very large/quite small" which is insufficient to be awarded credit. A numerical percentage comparison is required.

Estimating uncertainties

(b)(ii) Most candidates were familiar with the equation for calculating percentage uncertainty, though some made too small an estimate of the absolute uncertainty in the value of A , typically 1 small square on the grid (0.04 cm^2).

Evaluation

(f) Many candidates recognised that two sets of data were insufficient to draw a valid conclusion. Several candidates identified the measurement of A as a possible source of error, but without explaining why. A good explanation would be to state that the circle drawn was inaccurate because the plastic cup bends as the pencil is moved around it.

Many identified the difficulty of judging exactly when the cup hits the bottom, in particular because the cup is falling inside a bucket so must be viewed from above. Another limitation was the uneven descent of the cup, often hitting the sides of the bucket, owing to the mass being on one side of the cup.

Suggestions that were not credited included applying a force when releasing the cup (an extremely large force would have to be applied to have any effect on the time taken by the cup to fall to the bottom of the bucket).

Valid improvements included taking more readings (for different hole sizes) and then plotting a suitable graph to test the suggested relationship, and using a number of smaller masses evenly distributed around the base of the cup (a ring of adhesive putty was one good suggestion). Many candidates suggested using a clear or transparent bucket. There were a number of good suggestions for cutting a more circular hole (and then calculating the area using $\pi d^2/4$) using, for example, a circular cutter or a laser cutter. Other alternatives included pressing the base of the cups onto an inepad and then placing this on the grid.

Many candidates suggested the use of 'better' equipment or computers/data loggers/sensors without describing how such equipment would be used. Credit is not given for suggestions that could be carried out in the original experiment, such as repeating measurements or avoiding parallax errors by looking at eye level. General answers such as 'systematic error' or 'use an assistant' are not given credit.

The key to this section is for candidates to identify genuine problems associated with setting up this experiment and in obtaining readings. Candidates are encouraged to suggest detailed practical solutions that either improve technique or give more reliable data.

PHYSICS

Paper 9702/36
Advanced Practical Skills 2

Key Messages

- Candidates should take care in using appropriate precision for all of their measurements. The correct precision is principally determined by the precision of the measuring instrument being used. It is important not to record answers with insufficient precision, and similarly important not to add extra zeros to recorded values to give a false impression of greater precision.
- If a candidate restricts measurements to a small part of the available range, the scatter of points plotted on a graph grid is increased. This can make it more difficult to identify a trend and harder to choose a line of best fit. Candidates should be encouraged to use a range that is as wide as possible when taking measurements.
- Many candidates may gain more credit by being alert to units. Measurements should always be recorded with units, and most calculated quantities also require units in order to be valid. The omission of units is a common cause of lost credit.
- To score highly on **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. General points such as “avoid parallax error” or “use more precise measuring instruments” will not usually gain credit without further detail.

General Comments

The general standard of work was good and candidates in general were well prepared.

Most Centres carefully provided the equipment required. In some Centres, a large number of candidates were given help with the circuit in **Question 1**. This could indicate that candidates in these Centres would benefit from being given more practical experience of setting up circuits, perhaps by using questions from past papers. Supervisors are reminded that under **no circumstances** should help be given with the recording of results, graphical work or analysis.

Good answers in **Question 1** showed candidates were familiar with using a voltmeter and were able to manipulate the position of the crocodile clip to produce a zero reading. These answers showed a careful choice of scales to spread the plots over more than half the graph grid, with read-offs clearly shown at the corners of a large triangle used to determine the gradient and intercept of a well-drawn straight line. The link was made correctly between gradient and intercept values and the constants in the equation.

In **Question 2**, strong candidates were able to measure the bottle length and water depth to the nearest mm. Good answers showed accurate calculation, careful timing of oscillations and an understanding that the absolute uncertainty in time in **2(d)(iii)** was greater than the smallest division (precision) of a stopwatch. Clear thinking produced good suggestions for improved methods for measuring bottle length and oscillation time.

It would benefit all candidates to study the section Tips for Practical Papers in the Cambridge Learner Guide to gain an understanding of what is expected in **Question 1**. This can be viewed on the website www.cie.org.uk

Comments on Specific Questions

Question 1

The experiment involved using a bridge circuit and a null method to investigate a secondary circuit for a range of resistors inserted into that secondary circuit.

Successful collection of data

- (a) (ii) The majority of candidates correctly set up the initial circuit and produced a voltmeter reading in range. Good answers gave the correct unit of volt.
- (b) (ii) Stronger candidates were able to produce a zero reading. Once candidates realised the unit was not given on the answer line, good answers included the unit.
- (c) Most candidates were able to collect a full set of data, including six or more sets of values.

Range and distribution of values

- (c) Good answers used the full range of resistors. Time was well spent here to examine all the resistors and form a plan of which resistors to use in order to give as wide a range as possible with six sets of readings.

Quality of data

- (d) (iii) Good answers had points lying close to the drawn line, indicating that the quality of the data was good when judged by the amount of scatter about a straight-line trend on the graph.

Table

- (c) The majority of centres had done well in preparing candidates to present their raw readings clearly in a well drawn table. Candidates were able to tabulate their results for different values of the resistor R using appropriate column headings. Good answers used the guidance in the question carefully and included values of R , l , $1/R$, and $1/l$ in their tables.

Good answers had column headings containing the quantity and suitable units. These answers used the solidus (/) to act as a separator between the quantity and the unit e.g. $1/l / \text{m}^{-1}$ and $1/R / \text{k}\Omega^{-1}$. Candidates should be advised not to use a comma as a separator.

Many candidates correctly recorded values of l to the same number of decimal places.

The values of $1/R$ were generally calculated correctly. Candidates who thought carefully about significant figures and rounding gave good answers. For example with $R = 0.22 \text{ k}\Omega$ the calculator would show $1/R = 4.545$. Consequently, 4.5 and 4.55 were correct but not 4.54.

The number of significant figures in the calculated values of $1/l$ needed careful thought. When writing the calculated value, stronger candidates used the number of significant figures in the original l value as their guide for the number of significant figures to give in their value of $1/l$.

Graph

- (d) (i) Reflecting good preparation by Centres, the standard of graph work was usually high. Good answers showed candidates choosing “user-friendly” scales, i.e. scales that could easily be interpreted and points that could be checked without the use of a calculator. Ideally scales based on 2, 4, 5 or 10 should be used. Awkward scales based on 3 should not be used. A scale which leads to one of the points lying off the printed grid should not be used.

Axes when done well were labelled every one or two large squares along the whole axis.

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

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

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

Interpretation of graph

- (d)(iii) Good responses showed candidates had been well prepared on how to find the gradient and intercept values of a straight line graph. For the gradient, a large triangle was chosen where the hypotenuse used was longer than half the length of the drawn line, and read-offs were accurately taken from points on the line. Candidates looking for points on the line that could be read easily produced good answers. Candidates should be discouraged from using table values, as these often do not lie on the line and so cannot be awarded credit.

Good answers used read-offs correctly, with clear working showing $\Delta y/\Delta x$, before writing the calculated value of the gradient on the answer line. If the x-axis included the value $x = 0$, then the intercept could be directly read from the graph.

If $x = 0$ is not shown on the grid, candidates need to understand that they should calculate the y-intercept rather than choosing to extend the line below the grid in an attempt to estimate a read-off.

Drawing conclusions

- (e) Good answers showed a clear understanding of how the values found for gradient and intercept in (d)(iii) related to constants a and b . These showed a direct statement of the values with no need here for any recalculation. Candidates need to understand that it is not necessary to do any new calculations (often using simultaneous equations).

The best answers included correct consistent units, and had the powers of ten and units correct. Candidates need to practice how to work out the units of constants in an equation.

Question 2

This experiment involved timing pendulum-like oscillations for a partially filled suspended bottle.

Successful collection of data

- (a)(ii) Good answers showed candidates had made a good attempt to measure the bottle length to the nearest mm. Candidates who had added a zero, e.g. 185.0mm, or used the wrong unit, e.g. 18.5mm, were not given credit.
- (b) Good answers showed the distance d had been measured correctly and the fraction $c = d/L$ calculated by noting d was the numerator.

Correct justification for the number of significant figures in c was given in good answers by referring to the number of significant figures in d and L and stating these two quantities specifically. The term 'raw data' or discussions in terms of 'the quantity with the smallest number of significant figures' (without identifying specifically the quantities involved) did not gain credit.

- (d)(ii) Candidates should be encouraged to repeat their readings and calculate the average time before moving on to the next part of the experiment. Good answers showed repeat values, calculations of an average value of t , and were presented with the correct unit. Strong candidates recorded a value of t of approximately 8s, but weaker answers indicated a misread stopwatch with a time recorded as 0.08s. Some candidates did not read the question sufficiently carefully, and recorded the time for one swing.

- (e) Good answers showed candidates had added water until the bottle was approximately $\frac{3}{4}$ full.

Quality of data

- (e) Most candidates were able to obtain the correct trend, i.e. more water gave a smaller time.

Display of calculation and reasoning

- (c) Most candidates correctly calculated q .
- (f) (i) Good answers showed clear working and correct calculation of two values of k . Candidates needed to rearrange the equation correctly to find k (not $1/k$) by ensuring that t^2/q was correctly found rather than q/t^2 .

Drawing conclusions

- (f) (ii) Strong candidates calculate the percentage difference between the two k values, state a percentage value they will use as a criterion for comparison, and go on to use this percentage criterion to decide if the relationship is valid or not. One possible criterion is the percentage uncertainty found earlier in (d)(iii). It is helpful for the candidates to refer to percentage uncertainty rather than using the term 'experimental accuracy'.

If the percentage difference between the two k values is less than the criterion stated by the candidate, then the candidate should state that the relationship is supported. Candidates should understand that if the value of the percentage difference is greater than the value of the percentage stated as the criterion, then the relationship is not supported and the candidate needs to state this explicitly, i.e. 'the relationship is not supported'.

Candidates should understand that stating the difference between the two k values is 'small' or 'large' without quantification is not sufficient. Candidates also need to understand that using rounding to 'make' the k values equal will not gain credit.

Estimating uncertainties

- (d)(iii) Most candidates correctly calculated the percentage uncertainty of their t value, showing the method. The best answers estimated the absolute uncertainty in time between 0.2 and 0.5s. It was right to decide not to use the minimum scale division on the stopwatch, but rather to take account of reaction time.

Evaluation

- (g) The best answers were characterised by detailed suggestions specific to this experiment, where the major challenges were accurate measurement of lengths d and L and knowing/identifying when an oscillation finished and consequently knowing when to stop the stopwatch.

Candidates had plenty of time to measure the depth d of water, so the estimation of $\frac{1}{2}$ full or $\frac{3}{4}$ full was not an issue. The idea that it was difficult to estimate $\frac{1}{2}$ or $\frac{3}{4}$ full would not be a significant source of error.

In general, strong candidates stated a limitation with the reason why it was difficult to take the measurement. Good answers tried to link the problem encountered with the measurement it affected, e.g. 'it was difficult to measure L because the bottle was suspended and moved when the ruler touched it'. An answer of 'it was difficult to measure L ' is not detailed enough to gain credit.

Many good answers were characterised by including the suggestion that only two sets of readings for two different depths were not enough. A valid improvement is to take more readings with a wider variety of d values and plot a graph. Candidates need to understand that 'take more readings', which could mean just more repeat readings, or suggesting 'taking the average' are not good enough. If repeating and averaging is appropriate, this should already have been done and cannot be credited as an improvement.

Many candidates suggested the use of 'better' equipment or computers/data loggers/sensors without describing how such equipment would be used. Credit is not given for suggestions that

could be carried out in the original experiment, such as repeating measurements or avoiding parallax errors by looking at eye level. General answers such as 'systematic error' or 'use an assistant' are not given credit.

The key to this section is for candidates to identify genuine problems associated with setting up this experiment and in obtaining readings. Candidates are encouraged to suggest detailed practical solutions that either improve technique or give more reliable data.

PHYSICS

Paper 9702/41
A2 Structured Questions

Key Messages

- In order to achieve a high mark, candidates need to be able to demonstrate an understanding of their knowledge of physics. A wide experience of questions from past papers can be very useful in practising the skills needed to demonstrate this knowledge.
- Candidates must be able to explain their work fully. In particular, where an answer is given, relevant formulae should be quoted and full substitution of values made clear. This is particularly important in “show that” questions and those that make an explicit statement of “explain your working”. Candidates often lose credit where working is not shown clearly.
- Candidates sometimes produce answers that are clearly not of a sensible order of magnitude. When this is the case, they should go back and quickly check their working to see if they can establish the reason.

General Comments

The paper contained some straightforward questions which required a good memory and an understanding of the syllabus content. It also contained sections of questions where candidates had to apply their knowledge to, perhaps, unfamiliar situations. The result was that there was a wide distribution of marks, with high marks being scored by well-prepared candidates.

Question 13 was not well answered in general, suggesting that the topic of the mobile phone system had not been studied in detail.

Well-prepared candidates appeared to have sufficient time to complete their answers. There were few scripts where all parts of the questions had not been attempted.

Comments on Specific Questions

Section A

Question 1

- (a) With few exceptions, this simple substitution was completed successfully.
- (b) Most candidates did realise that they could use the expression mgh for the change in potential energy. The instruction that the working should be explained was rarely followed. Consequently, very few answers contained enough explanation to be given full credit.
- (c) Many candidates used the correct expression to determine the speed, although a significant minority attempted to use the same expression as in (b). The most common problem was in the substitution for the distance. Many candidates used either D or $3.5D$ rather than $4D$. Candidates should be encouraged to look carefully at the diagram, which might have made this type of mistake less likely.

Question 2

- (a) (i) A significant number of candidates found difficulty in resolving the reaction force into two components. Instead, they attempted to manipulate the given expression for W .
- (ii) Most did realise that the force F provides the centripetal force. There was only one mark awarded for this answer, but some candidates attempted to write a long description of the effect that this force would have on the motion of the ball.
- (b) This was generally answered well, although a significant number gave the answer as 2.58 ms^{-1} , having not taken the square root. This is a relatively common error in this type of calculation.

Question 3

- (a) In most answers, the equation of state was quoted. Some merely stated $pV = \text{constant}$ or wrote out assumptions of the kinetic theory of gases.
- (b) (i) With very few exceptions, the calculation was completed with sufficient explanation.
- (ii) This calculation was quite difficult for many candidates. A correct approach is to find the loss in mol and then to convert this loss to the number of atoms, before finding the rate. A common error was to confuse the amount remaining in the cylinder with the amount lost. Many candidates made a simple power-of-ten error in the percentage loss.

Question 4

- (a) Most definitions were correct.
- (b) (i) The number of fully correct answers was limited. In many scripts, it was not made clear that g and r are constants, thus leading to the proportionality condition. Where this proportionality condition was discussed, the significance of the negative sign was frequently omitted.
- (ii) The basic theory for this calculation presented few problems. A common mistake was to give the answer as the period, not realising that the time interval would be one half of this.
- (c) It was expected that a smooth curve would be drawn, with the same period and with peak values decreasing progressively, but not to a great extent. Most drew a curve with the correct period but many did not show successive decreases in the amplitude at the peaks.

Question 5

- (a) In general, definitions were correct. A common mistake was omitting to refer to a *unit positive* charge.
- (b) (i) It was expected that candidates would deduce that, inside the sphere, the potential would be constant. Many answers were based on the idea that the radius must be less than where the graph line starts.
- (ii) For a point charge, the product Vx would be constant. Candidates were expected to choose two widely separated points and to draw a conclusion based on the product Vx being constant. There were very few answers that went beyond a statement that Vx should be constant.
- (c) This straightforward calculation was completed successfully by most candidates.

Question 6

- (a) In most scripts, this calculation was completed correctly. Common errors were either to omit the angle function or to use an incorrect angle function.
- (b) Most candidates calculated the peak current along with the force associated with this current. There were few answers where the force associated with the peak current was doubled. Many determined the difference between this force and that calculated in (a).

Question 7

- (a) (i) It was expected that the explanation would be based on either heating effect being proportional to the square of the current or on heating effect being independent of current direction. Many answers were based on either eddy currents being induced or charge carriers causing atoms to vibrate.
- (ii) The meaning of r.m.s. value was not widely understood. In many answers, there was no clear reference to a value of a direct current. Many explanations were based on mathematical considerations of peak and/or r.m.s. values without reference to heating effect.
- (b) (i) The law was quoted satisfactorily by the majority of candidates.
- (ii) Very few answers gave a clear explanation. It was expected that reference would be made to the phase angle between the current in the primary and the flux in the core, the phase angle between the flux in the core and the e.m.f in the secondary and thus the phase angle between primary current and secondary e.m.f. Very few answers progressed beyond a statement relevant to flux in the core and e.m.f. induced in the secondary coil.

Question 8

- (a) In many instances, answers lacked the necessary detail of the physics of the situation. Very frequently, reference was made to 'light absorbed by atoms of gas' rather than the more precise explanation of photons 'absorbed' by electrons as they move to higher energy levels. The reason why the wavelengths appear to be missing was not appreciated by many candidates.
- (b) (i) Most attempts at this calculation were successful although, in a considerable number of scripts, the energy in joules was not converted to eV.
- (ii) The correct transition was usually shown in those scripts where the calculation in (i) had been completed successfully.

Question 9

- (a) It was expected that a reference would be made to 'light' nuclei combining to form a 'heavier' nucleus. In many scripts, there was confusion between nuclei, atoms, nuclides and nucleons. The distinction between these terms is important. In some scripts, it was not clear that it is 'light' nuclei that combine.
- (b) (i) In some scripts, an answer was quoted without any working, despite the instruction to explain your working. Others attempted to use data from Fig. 9.1. It was expected that a three significant figure answer would be calculated, starting with the expression $\Delta E = c^2 \Delta m$.
- (ii) It was expected that Δm would be calculated and then this would be multiplied by the answer in (i). There were many instances where Δm was not determined correctly.
- (iii) In many answers, reference was made to the fact that there would be repulsion between the deuterium and the tritium nuclei. It was expected that a clear statement would be made to the effect that the kinetic energy of these nuclei would need to be very high so that the nuclei could approach one another and thus fusion could take place.

Section B

Question 10

- (a) Most candidates could give three properties of an ideal op-amp.
- (b) (i) It should be emphasised to candidates that, where a task uses the key word *Show*, then full explanation is required. The starting point was to quote the resistance of the thermistor at 1.0°C. Frequently, a clear statement was not made. The answer was given as -0.20V. In many instances, the negative sign appeared without any explanation.
- (ii) This was generally completed successfully.

- (c) (i) There were comparatively few correct answers. A large number of answers were found as $(0.35/29) \times 15$.
- (ii) Although most candidates did refer to a non-linearity with temperature, many candidates described the voltmeter reading rather than the thermistor resistance as being non-linear.

Question 11

- (a) In most answers, no mention was made of the fact that the X-ray tube would produce a spectrum of wavelengths. There were relatively few references to X-ray wavelengths or frequencies; more often 'soft' or 'hard' X-rays were mentioned without explaining these terms. Some candidates incorrectly stated that the filter is used to absorb scattered X-rays.
- (b) In most answers, it was appreciated that a CT scan would give rise to a larger exposure. Candidates should be encouraged to be more precise. Vague wording such as 'many X-rays are needed' was common. Candidates would have been more successful if they had referred to the need in a CT scan for X-ray images to be taken from many angles for each slice.

Question 12

- (a) There were many complete answers, but others where an adequate level of detail was not provided. Some indication of what is being linked was required. For example, a co-axial cable could be used 'to link a TV to an aerial'; an answer of 'aerial' was not sufficiently detailed to be awarded credit.
- (b) (i) The calculation was completed successfully by many candidates. The most common problem was an inversion of the ratio so that, despite being told that the signal is attenuated, the power received by the satellite was found to be 3.1×10^{19} kW. A quick check of the received power compared with the transmitted power should have revealed this to be an error.
- (ii) It was appreciated by most candidates that the signal must be amplified and that the frequency is changed. A statement 'to prevent swamping' was not considered to be adequate explanation.

Question 13

- (a) Many candidates suggested that the switch functioned either to switch on power to the phone or that it was responsible for the transmission and reception of signals.
- (b) Some candidates did state that the tuning circuit 'selects the signal'. Very few gave a precise statement that the circuit gives a large output for one frequency and very small output for all other frequencies. A common misconception was that the tuning circuit selects the frequency for communication with the base station.

PHYSICS

Paper 9702/42
A2 Structured Questions

Key Messages

- In order to achieve a high mark, candidates need to be able to demonstrate an understanding of their knowledge of physics. A wide experience of questions from past papers can be very useful in practising the skills needed to demonstrate this knowledge.
- Candidates must be able to explain their work fully. In particular, where an answer is given, relevant formulae should be quoted and full substitution of values made clear. This is particularly important in “show that” questions and those that make an explicit statement of “explain your working”. Candidates often lose credit where working is not shown clearly.
- Candidates sometimes produce answers that are clearly not of a sensible order of magnitude. When this is the case, they should go back and quickly check their working to see if they can establish the reason.

General Comments

The paper contained some straightforward questions which required a good memory and an understanding of the syllabus content. It also contained sections of questions where candidates had to apply their knowledge to, perhaps, unfamiliar situations. The result was that there was a wide distribution of marks, with high marks being scored by well-prepared candidates.

Question 13 was not well answered in general, suggesting that the topic of the mobile phone system had not been studied in detail.

Well-prepared candidates appeared to have sufficient time to complete their answers. There were few scripts where all parts of the questions had not been attempted.

Comments on Specific Questions

Section A

Question 1

- (a) With few exceptions, this simple substitution was completed successfully.
- (b) Most candidates did realise that they could use the expression mgh for the change in potential energy. The instruction that the working should be explained was rarely followed. Consequently, very few answers contained enough explanation to be given full credit.
- (c) Many candidates used the correct expression to determine the speed, although a significant minority attempted to use the same expression as in (b). The most common problem was in the substitution for the distance. Many candidates used either D or $3.5D$ rather than $4D$. Candidates should be encouraged to look carefully at the diagram, which might have made this type of mistake less likely.

Question 2

- (a) (i) A significant number of candidates found difficulty in resolving the reaction force into two components. Instead, they attempted to manipulate the given expression for W .

- (ii) Most did realise that the force F provides the centripetal force. There was only one mark awarded for this answer, but some candidates attempted to write a long description of the effect that this force would have on the motion of the ball.
- (b) This was generally answered well, although a significant number gave the answer as 2.58 ms^{-1} , having not taken the square root. This is a relatively common error in this type of calculation.

Question 3

- (a) In most answers, the equation of state was quoted. Some merely stated $pV = \text{constant}$ or wrote out assumptions of the kinetic theory of gases.
- (b)(i) With very few exceptions, the calculation was completed with sufficient explanation.
- (ii) This calculation was quite difficult for many candidates. A correct approach is to find the loss in mol and then to convert this loss to the number of atoms, before finding the rate. A common error was to confuse the amount remaining in the cylinder with the amount lost. Many candidates made a simple power-of-ten error in the percentage loss.

Question 4

- (a) Most definitions were correct.
- (b)(i) The number of fully correct answers was limited. In many scripts, it was not made clear that g and r are constants, thus leading to the proportionality condition. Where this proportionality condition was discussed, the significance of the negative sign was frequently omitted.
- (ii) The basic theory for this calculation presented few problems. A common mistake was to give the answer as the period, not realising that the time interval would be one half of this.
- (c) It was expected that a smooth curve would be drawn, with the same period and with peak values decreasing progressively, but not to a great extent. Most drew a curve with the correct period but many did not show successive decreases in the amplitude at the peaks.

Question 5

- (a) In general, definitions were correct. A common mistake was omitting to refer to a *unit positive* charge.
- (b)(i) It was expected that candidates would deduce that, inside the sphere, the potential would be constant. Many answers were based on the idea that the radius must be less than where the graph line starts.
- (ii) For a point charge, the product Vx would be constant. Candidates were expected to choose two widely separated points and to draw a conclusion based on the product Vx being constant. There were very few answers that went beyond a statement that Vx should be constant.
- (c) This straightforward calculation was completed successfully by most candidates.

Question 6

- (a) In most scripts, this calculation was completed correctly. Common errors were either to omit the angle function or to use an incorrect angle function.
- (b) Most candidates calculated the peak current along with the force associated with this current. There were few answers where the force associated with the peak current was doubled. Many determined the difference between this force and that calculated in (a).

Question 7

- (a)(i) It was expected that the explanation would be based on either heating effect being proportional to the square of the current or on heating effect being independent of current direction. Many

answers were based on either eddy currents being induced or charge carriers causing atoms to vibrate.

- (ii) The meaning of r.m.s. value was not widely understood. In many answers, there was no clear reference to a value of a direct current. Many explanations were based on mathematical considerations of peak and/or r.m.s. values without reference to heating effect.
- (b)(i) The law was quoted satisfactorily by the majority of candidates.
- (ii) Very few answers gave a clear explanation. It was expected that reference would be made to the phase angle between the current in the primary and the flux in the core, the phase angle between the flux in the core and the e.m.f in the secondary and thus the phase angle between primary current and secondary e.m.f. Very few answers progressed beyond a statement relevant to flux in the core and e.m.f. induced in the secondary coil.

Question 8

- (a) In many instances, answers lacked the necessary detail of the physics of the situation. Very frequently, reference was made to 'light absorbed by atoms of gas' rather than the more precise explanation of photons 'absorbed' by electrons as they move to higher energy levels. The reason why the wavelengths appear to be missing was not appreciated by many candidates.
- (b)(i) Most attempts at this calculation were successful although, in a considerable number of scripts, the energy in joules was not converted to eV.
- (ii) The correct transition was usually shown in those scripts where the calculation in (i) had been completed successfully.

Question 9

- (a) It was expected that a reference would be made to 'light' nuclei combining to form a 'heavier' nucleus. In many scripts, there was confusion between nuclei, atoms, nuclides and nucleons. The distinction between these terms is important. In some scripts, it was not clear that it is 'light' nuclei that combine.
- (b)(i) In some scripts, an answer was quoted without any working, despite the instruction to explain your working. Others attempted to use data from Fig. 9.1. It was expected that a three significant figure answer would be calculated, starting with the expression $\Delta E = c^2\Delta m$.
- (ii) It was expected that Δm would be calculated and then this would be multiplied by the answer in (i). There were many instances where Δm was not determined correctly.
- (iii) In many answers, reference was made to the fact that there would be repulsion between the deuterium and the tritium nuclei. It was expected that a clear statement would be made to the effect that the kinetic energy of these nuclei would need to be very high so that the nuclei could approach one another and thus fusion could take place.

Section B

Question 10

- (a) Most candidates could give three properties of an ideal op-amp.
- (b)(i) It should be emphasised to candidates that, where a task uses the key word *Show*, then full explanation is required. The starting point was to quote the resistance of the thermistor at 1.0 °C. Frequently, a clear statement was not made. The answer was given as -0.20 V. In many instances, the negative sign appeared without any explanation.
- (ii) This was generally completed successfully.
- (c)(i) There were comparatively few correct answers. A large number of answers were found as $(0.35/29)\times 15$.

- (ii) Although most candidates did refer to a non-linearity with temperature, many candidates described the voltmeter reading rather than the thermistor resistance as being non-linear.

Question 11

- (a) In most answers, no mention was made of the fact that the X-ray tube would produce a spectrum of wavelengths. There were relatively few references to X-ray wavelengths or frequencies; more often 'soft' or 'hard' X-rays were mentioned without explaining these terms. Some candidates incorrectly stated that the filter is used to absorb scattered X-rays.
- (b) In most answers, it was appreciated that a CT scan would give rise to a larger exposure. Candidates should be encouraged to be more precise. Vague wording such as 'many X-rays are needed' was common. Candidates would have been more successful if they had referred to the need in a CT scan for X-ray images to be taken from many angles for each slice.

Question 12

- (a) There were many complete answers, but others where an adequate level of detail was not provided. Some indication of what is being linked was required. For example, a co-axial cable could be used 'to link a TV to an aerial'; an answer of 'aerial' was not sufficiently detailed to be awarded credit.
- (b)(i) The calculation was completed successfully by many candidates. The most common problem was an inversion of the ratio so that, despite being told that the signal is attenuated, the power received by the satellite was found to be 3.1×10^{19} kW. A quick check of the received power compared with the transmitted power should have revealed this to be an error.
- (ii) It was appreciated by most candidates that the signal must be amplified and that the frequency is changed. A statement 'to prevent swamping' was not considered to be adequate explanation.

Question 13

- (a) Many candidates suggested that the switch functioned either to switch on power to the phone or that it was responsible for the transmission and reception of signals.
- (b) Some candidates did state that the tuning circuit 'selects the signal'. Very few gave a precise statement that the circuit gives a large output for one frequency and very small output for all other frequencies. A common misconception was that the tuning circuit selects the frequency for communication with the base station.

PHYSICS

Paper 9702/43
A2 Structured Questions

Key Messages

- In order to achieve a high mark, candidates need to be able to demonstrate an understanding of their knowledge of physics. A wide experience of questions from past papers can be very useful in practising the skills needed to demonstrate this knowledge.
- Candidates must be able to explain their work fully. In particular, where an answer is given, relevant formulae should be quoted and full substitution of values made clear. This is particularly important in “show that” questions and those that make an explicit statement of “explain your working”. Candidates often lose credit where working is not shown clearly.
- Candidates sometimes produce answers that are clearly not of a sensible order of magnitude. When this is the case, they should go back and quickly check their working to see if they can establish the reason.

General Comments

The marks scored by candidates ranged widely. Some candidates showed a very high level of preparation, and demonstrated an excellent knowledge of physics and the ability to apply it.

There were some improvements in the ability of candidates to answer the questions in **Section B**. However, this was Centre dependent, and some Centres did not appear to have spent sufficient time teaching this section. Since 30% of the marks are awarded for this section, it would be expected that a similar percentage of teaching time should be spent on these topics.

Candidates should be encouraged to spend much more time and care on drawing diagrams correctly, as these were sometimes hurried and inaccurate, even amongst the more able candidates taking the paper.

The majority of candidates attempted parts of the whole examination paper showing they had sufficient time to complete their answers. Those that were less well prepared had significant omissions in their question papers.

Comments on Specific Questions

Section A

Question 1

- (a) (i) Most candidates were able to establish the time period correctly from the graph and then went on to calculate the angular frequency. A small number incorrectly used 0.6 s as the time period.
- (ii) The answer to this part was provided. Most candidates were able to apply the relevant formula for the energy of oscillations in order to arrive at the required answer. Some approached the calculation in two stages, calculating the maximum velocity before the energy.
- (b) (i) Most candidates started with a statement of Faraday’s law of electromagnetic induction. However, many were unable to apply it to this situation. A common mistake was to say that the change of flux cutting the cup gave rise to a current rather than an e.m.f. The converse of this was to incorrectly say that the energy loss was due to the induced e.m.f. rather than the current.

- (ii) This was a similar calculation to that in (a)(ii) and, again, many candidates had few problems deriving the final answer. These candidates found the energy at 0.75 cm and subtracted it from the initial energy to get the correct answer. Candidates must note that the energy loss is not found by using the kinetic energy of a particle oscillating with amplitude a and having displacement x .
- (c) Answers were usually correct. A few candidates initially calculated the correct value but then added 273 to their answer as they saw that the unit of kelvin was given. These candidates did not realise that they were being asked for a temperature rise, which is the same in both temperature scales. Some divided by 10 to obtain the mean temperature rise per oscillation.

Question 2

- (a) Relatively few graphs obtained full credit. Many graphs inappropriately showed a finite value of gravitational field strength at zero distance from the point mass. Many candidates needed to take more care when drawing the gradient at both ends of the graph line.
- (b) Most candidates were awarded full credit. Candidates should be encouraged to draw straight lines with a ruler and not freehand.
- (c) Only a small number of graphs had the correct sinusoidal shape. The most common incorrect answer was to draw a rectified sine curve rather than a \sin^2 curve. Several candidates confused this situation with half-wave rectification.

Question 3

- (a) There were many different methods used. Commonly, the value of pV/T or the value of n was calculated for both the initial and final states. Candidates should realise that it is appropriate to calculate these values to 3 s.f. as all the data in the question is given to 3 s.f. Candidates also needed to ensure that their calculated values did not contain rounding errors. Some candidates showed a relation between V and T but did not mention the constant P in their summary. The most successful answers clearly explained each step of their calculation and finished with a clear concluding statement.
- (b)(i) Most candidates were able to successfully answer this. A small number did the correct working and then unfortunately wrote down 288 J rather than 228 J as their answer.
- (ii) The gas has expanded and so work is done by the gas. Many candidates did not establish that the work done was therefore negative and they did not subtract 228 J from 569 J. Some candidates did the correct subtraction, but then because they had subtracted the work they thought there was an overall decrease in internal energy.

Question 4

- (a) In general, candidates were able to give a correct statement.
- (b)(i) Whilst there were many correct answers, some candidates thought that the equilibrium position corresponded to a time on the graph where the velocity is zero. Others wrongly stated two non-subsequent times at which the trolley moves through the equilibrium position. A few answers were given going backwards in time and some candidates did not read the graph scale accurately.
- (ii) 1. Most answers were correct.
2. The weakest candidates often divided $v_0/2$ by ω to give an incorrect displacement of 1.6 cm. The most common correct solution was to use the equation given on the formula sheet that relates velocity to displacement. A few candidates calculated the corresponding time and then used this time to find the displacement.
- (c) It was clear that most candidates were not familiar with the graphical representation of this formula. There were many straight lines and many sine waves given as answers. Of those who did draw a loop, many showed only the top half of the loop and others did not use their previous answers to include a scale on the y -axis. Although the command term 'sketch' implies that the shape and position need only be qualitatively correct, candidates should be aware that some quantitative aspects, such as intercepts, may be looked for.

Question 5

- (a) In the majority of cases a correct definition was given. Weaker candidates sometimes missed out 'unit' or 'positive' from their description of the charge.
- (b)(i) This was generally well answered, but a number of candidates made two power of ten errors. When answers are clearly not of a sensible order of magnitude for the radius of a metal sphere, candidates should be encouraged to go back and check their working. Many candidates incorrectly substituted 9×10^9 for $4\pi\epsilon_0$.
- (ii) There were many incorrect responses here as candidates forgot the $\frac{1}{2}$ in the energy formula. Weaker candidates confused E , field strength, with energy.
- (c) Many answers used the equation $V = Er$ without explanation and so gained only partial credit. The most successful answers initially calculated the maximum charge on the sphere and then used this to calculate the maximum potential. Another mistake was to use $E = V/d$, the equation for a uniform field.

Question 6

- (a) There were many answers given here. Occasionally candidates gave an answer of 0.03125 and forgot or did not realise that they needed to give the reciprocal of this value. A few weak candidates treated the capacitors as resistors leading to an answer of 72 F.
- (b) This proved a difficult question. Many candidates did not know what would be the total p.d. across two identical capacitors in parallel. The most successful route was to find the charge on the single capacitor, equate this to the total charge stored in the network, and hence find the p.d. between A and B. Some candidates used the idea of reciprocals with the p.d. which is incorrect physics (even though it does mathematically lead to the correct answer).

Question 7

- (a) There were many confused or incomplete statements of what is meant by quantisation of charge. Whilst many of the stronger candidates appreciate that charge exists in discrete amounts, few were explicit in stating that it is in discrete and equal amounts or multiples of a fundamental amount.
- (b)(i) Although there were good responses here, some gave the field direction only with no reference to the direction of force needed. Weaker candidates thought the direction of the magnetic field should be opposite to the direction of the electric field. Responses like 'into the plane' are ambiguous as it not clear whether the plane of the plate or the question paper is intended.
- (ii) This sketch should be drawn with care, and on Fig. 7.1 rather than another version of it. Many paths drawn were poor because the curvature started only after a considerable distance into the field.

Question 8

- (a) Well prepared candidates had little difficulty.
- (b)(i) This was well answered, but candidates must substitute to show that they understand the meanings of all quantities used.
- (ii) 1. There were many good answers. A common error was to calculate the power arriving per square metre. Others calculated an answer that was less than 1, but did not seem to realise that this was not a sensible value.
2. Many candidates calculated the momentum change of 1 photon here rather than all the photons in 1.0s, so they need to be encouraged to read questions more carefully. A small number of candidates thought that the photons were reflected and so determined an answer twice as large as the correct answer. Again, these candidates should read the detail of the question more carefully. Others inappropriately attempted to calculate the mass of a photon during their working.

- (c) Many candidates gained full credit here. Some candidates who had not included the number of photons in 1.0 s did so here and hence did arrive at the correct answer in order to gain full credit.

Question 9

- (a) Almost without exception, a correct answer was given.
- (b)(i) There were few correct answers. Often the energy of a single β -particle was stated as the final answer or else the conversion from MeV to J was missing. This question required candidates to understand how the activity relates to the energy released and many candidates clearly did not understand this.
- (ii) There were many correct responses when the answer to (b)(i) was correct. A few candidates calculated the total energy released in the full mass of steel (2.5×10^6 kg) before deciding how this would affect the temperature. Some of the strongest candidates linked the specific heat capacity of steel into their answer. Some weaker candidates did not appreciate the effect a small quantity of energy can have on a large mass of steel, and said the temperature rise would be high.
- (iii) Although there were many fully correct answers, some candidates could only state the appropriate equations and could not progress further. When substituting the values into the symbol equations, sometimes an activity per unit mass was incorrectly compared with a total activity. Some candidates tried to calculate the number of nickel atoms by assuming that there was 2.5×10^6 kg of nickel (rather than steel). Candidates would be advised to look at the unit of the answer as many spent valuable time unnecessarily converting from years to seconds.

Section B

Question 10

- (a)(i) Answers were usually correct. The most common correct answer was 'thermistor', with very few opting for 'thermocouple'.
- (ii) Again, there were many correct answers.
- (b)(i) Those who understood the operational amplifier usually scored well on this question. Others quoted the output potential as -5 V then failed to explain fully the reason for this. A correct answer should have had an explanation of why it was 5 V **and** why it was a negative output. The graphs produced in (b)(ii) showed that candidates often did understand the op-amp but found it difficult to express this in words. They would benefit from more practice of questions in this area from past exam papers.
- (ii) The majority of candidates were awarded partial credit for their graphs. Some drew a line that was a reflection of V_{IN} across the t axis. Some candidates had -5 V as the answer to (b)(i) but drew their graph as if the answer had been $+5$ V. In this way and others many drew lines that contradicted their previous answer.

Question 11

- (a) This question was well answered. Candidates should be encouraged to say that the speed of waves is that in the medium. A tiny minority confused the symbol c in the formula with the speed of light.
- (b)(i) Most candidates answered correctly. The word 'fraction' caused some confusion, and some candidates felt they must leave their answer as 2207/6415 or similar. Centres could explain that a decimal number answer is required at all times and the word 'fraction' is used for 'how much of'. Some candidates did not use the equation given in the stem but used their own (incorrect) equation instead.
- (ii) Many candidates showed good recall of this equation and were able to reach the correct answer. Some candidates did not convert the 3.4 cm of muscle into m.
- (iii) The method of combining the fractions from (i) and (ii) was not well understood, with few candidates realising that the key was to multiply them. Common mistakes were to divide or add

them instead. It was here that it became apparent that many candidates do not understand the physics of this reflection and transmission question. They need a mental model, such as: a fraction/portion/percentage is lost on transmission and a fraction/portion/percentage is lost on reflection. There are two transmission losses and one reflection loss, and each loss is cumulative, so it is necessary to multiply the fractions together. Stronger candidates were able to do this.

Question 12

- (a) Whilst most candidates understood what a digital signal was, they found it more difficult to explain an analogue signal. 'A signal that varies as the transmitted signal' was the most common incorrect answer. The idea of the analogue signal being continuously variable caused problems.
- (b)(i) This was reasonably well done. A common incorrect answer was 4.
- (ii) There were many correct answers. Some incorrect answers had the digits in reverse order.
- (c) Candidates found this question difficult. Most talked about the reproduced signal being more faithful to the original signal, but this is a general point and also applies if you increase the sampling rate. The correct answer requires a specific reference to the number of voltage levels that could be seen, so answers should relate to step height, changes in voltage levels and number of voltage levels.

Question 13

- (a) Very few candidates could explain the reason for dividing the country into cells. Many talked vaguely about each cell having a different carrier frequency without alluding to the idea that the same carrier frequency is reused. A common answer was to say that a cellular network ensures that the handsets always have a strong signal as they are never too far away from a base station. Others said that the cells enable the handsets to be relatively close to their nearest base station and this enables the handsets to have a smaller transmission power which is less of a health hazard to the user.
- (b) Although candidates did know some of the reasons for using UHF frequencies, they often described the advantage of using UHF frequencies without linking it to the associated property to give a full explanation. Where candidates stated that the UHF bandwidth is large, they often then wrote that this means more data can be carried with no mention of time.

PHYSICS

Paper 9702/51

Planning, Analysis and Evaluation

Key Messages

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

General Comments

All candidates were able to attempt the paper and there was no evidence of time constraints. The majority of the scripts were clearly written. The majority of graphs were well drawn with points and error bars easily identifiable. To gain maximum credit, it is essential that candidates show all of their working clearly; stronger candidates set out their working clearly and there was logical progression within their answers.

It is clear that the stronger 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 practical support booklets which are available from the Teacher Support Site.

Comments on Specific Questions

Question 1

Candidates were required to design a laboratory experiment to investigate how the power dissipated in a lamp connected to a wind turbine depends on the angle between the turbine and the direction of the wind. Candidates were also required to explain how they would verify the given equation and determine a constant from the measurements. The description of the experiment by candidates has improved but candidates could improve further by giving more detail in their answers.

The initial marks were awarded for correctly identifying the independent and dependent variables. Most candidates correctly realised that the angle θ was the independent variable and the power P was the dependent variable.

Further credit is then available for controlling variables: candidates should indicate how a fair test could be made by keeping appropriate variables constant. A significant number of candidates write "control" instead of "constant" for the constant variable and this was not credited. Candidates should also be aware of the difference between a constant and a variable that is to be held constant in the experiment. In this case credit was available for keeping the speed of the wind/air constant. Some candidates were credited for stating that the power of the fan was kept constant, and a mark for additional detail could have been scored for stating that the distance from the fan to the turbine should be constant. There was also a mark for the additional detail of explaining the method to check that the wind speed was constant—a wind speed detector (anemometer) needed to be shown in the diagram and an explanation given.

Five marks are available for the methods of data collection. Candidates were expected to include a diagram with a method to produce the wind, e.g. a labelled fan, and also a circuit diagram for the lamp. Circuit diagrams must be correct and clearly labelled using conventional symbols. Incorrect diagrams often had a battery in series with the turbine or the positioning of ammeters and voltmeters was incorrect.

To investigate the relationship, candidates needed to explain how the power would be determined from the measurements and how the angle would be determined. Some candidates assumed that the resistance of the lamp would be constant for all measurements. Some candidates suggested using trigonometry but then measured incorrect distances for the appropriate relationship. Credit was available for indicating how other draughts or airflows could be avoided. Stronger candidates explained clearly that other fans would be switched off or windows shut to avoid other air flows.

There are two marks available for the analysis of the data. It was expected that candidates would state the quantities that should be plotted on each axis of a graph for the first mark. Most candidates were successful, although a significant number of candidates omitted “cos”. The second analysis mark was awarded for explaining the determination of the value of k from an appropriate graph. There was also an additional mark was available for stating that the relationship would be valid if the data points on the graph are linear with a y -intercept equal to zero; some candidates did not state that the line had to be straight.

There was one mark available for describing an appropriate safety precaution. Candidates should be encouraged to give clearly reasoned safety precautions that are relevant to the experiment. In this case it was expected that they would describe a safety precaution relating either to preventing dust particles entering the eye or to avoiding the moving blades of the fan. Most candidates were awarded credit for the safety precaution.

There are four marks available for additional detail. Candidates should be encouraged to write their plans including appropriate detail; often candidates' answers suggested that they did not have sufficient practical experience. Vague responses were not credited. Those candidates who have followed a 'hands on' practical course are generally much better placed to score these additional detail marks. It is essential that candidates' give detail relevant to the experiment in question rather than general 'textbook' rules for working in a laboratory.

Question 2

In this data analysis question, candidates were given data on how the resonant frequency f in an electrical circuit is affected by capacitance C .

- (a) This question was generally answered well.
- (b) A number of candidates lost credit for rounding errors. It is expected that the number of significant figures in calculated quantities should be the same as, or one more than, the number of significant figures in the raw data. In this case, C was given to two significant figures so it was expected that $1/C$ would be given to two or three significant figures. Some candidates did not determine the absolute uncertainties in C correctly.
- (c) (i) Candidates should be advised to ensure that the size of the plotted points is small; large 'blobs' are not awarded credit. Candidates should be encouraged to check points that do not appear to follow the line of best fit. A number of candidates did not construct the error bars accurately, and some candidates plotted vertical error bars.
- (ii) Some candidates were careless in their drawing of the lines; candidates should be encouraged to use a transparent 30 cm ruler. They should also be encouraged to ensure that there is a balance of points on each side of the line. The worst acceptable straight line should be either the steepest possible line or the shallowest possible line that passes through all the error bars of all the data points used for the line of best fit. The majority of the candidates clearly labelled the lines on their graph; lines not indicated may not be credited. A number of candidates were not awarded credit for their lines since they were not straight. A significant number of candidates did not draw the worst acceptable line sufficiently accurately.
- (iii) This part was generally answered well; most candidates clearly demonstrated the points they had used to determine the gradient. Some candidates did not use a sensibly-sized triangle for their gradient calculation. A large number of stronger candidates clearly indicated the points that they

used from the line of best fit. Some candidates used their points from the table but did not gain credit because they did not lie on the line of best fit.

To determine the uncertainty in the gradient, candidates were expected to find the difference between the gradient of the line of best fit and the gradient of the worst acceptable line. Again stronger candidates clearly indicated the points that they used from the worst acceptable line. Some candidates were confused by which line was the best and which was the worst.

- (d) Candidates needed to determine a value for L using the gradient. A large number of candidates either omitted the unit or gave wrong units. Candidates were also required to give the absolute uncertainties in the values for L ; acceptable methods are given in the published mark scheme.
- (e) (i) The stronger candidates were able to determine a value of f in the required range and present it to an appropriate number of significant figures.
- (ii) For this question it is essential that candidates show their working. Many candidates did not realise that the percentage uncertainty was half the sum of the percentage uncertainties in the values of L and C . A common mistake was to use $0.1/10$ rather than $1/10$ when determining the maximum/minimum value of f . Appropriate methods to determine the percentage uncertainty are shown in the published mark scheme.

PHYSICS

Paper 9702/52

Planning, Analysis and Evaluation

Key Messages

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

General Comments

All candidates were able to attempt the paper and there was no evidence of time constraints. The majority of the scripts were clearly written. The majority of graphs were well drawn with points and error bars easily identifiable. To gain maximum credit, it is essential that candidates show all of their working clearly; stronger candidates set out their working clearly and there was logical progression within their answers.

It is clear that the stronger 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 practical support booklets which are available from the Teacher Support Site.

Comments on Specific Questions

Question 1

Candidates were required to design a laboratory experiment to investigate how the power dissipated in a lamp connected to a wind turbine depends on the angle between the turbine and the direction of the wind. Candidates were also required to explain how they would verify the given equation and determine a constant from the measurements. The description of the experiment by candidates has improved but candidates could improve further by giving more detail in their answers.

The initial marks were awarded for correctly identifying the independent and dependent variables. Most candidates correctly realised that the angle θ was the independent variable and the power P was the dependent variable.

Further credit is then available for controlling variables: candidates should indicate how a fair test could be made by keeping appropriate variables constant. A significant number of candidates write "control" instead of "constant" for the constant variable and this was not credited. Candidates should also be aware of the difference between a constant and a variable that is to be held constant in the experiment. In this case credit was available for keeping the speed of the wind/air constant. Some candidates were credited for stating that the power of the fan was kept constant, and a mark for additional detail could have been scored for stating that the distance from the fan to the turbine should be constant. There was also a mark for the additional detail of explaining the method to check that the wind speed was constant—a wind speed detector (anemometer) needed to be shown in the diagram and an explanation given.

Five marks are available for the methods of data collection. Candidates were expected to include a diagram with a method to produce the wind, e.g. a labelled fan, and also a circuit diagram for the lamp. Circuit diagrams must be correct and clearly labelled using conventional symbols. Incorrect diagrams often had a battery in series with the turbine or the positioning of ammeters and voltmeters was incorrect.

To investigate the relationship, candidates needed to explain how the power would be determined from the measurements and how the angle would be determined. Some candidates assumed that the resistance of the lamp would be constant for all measurements. Some candidates suggested using trigonometry but then measured incorrect distances for the appropriate relationship. Credit was available for indicating how other draughts or airflows could be avoided. Stronger candidates explained clearly that other fans would be switched off or windows shut to avoid other air flows.

There are two marks available for the analysis of the data. It was expected that candidates would state the quantities that should be plotted on each axis of a graph for the first mark. Most candidates were successful, although a significant number of candidates omitted “cos”. The second analysis mark was awarded for explaining the determination of the value of k from an appropriate graph. There was also an additional mark available for stating that the relationship would be valid if the data points on the graph are linear with a y -intercept equal to zero; some candidates did not state that the line had to be straight.

There was one mark available for describing an appropriate safety precaution. Candidates should be encouraged to give clearly reasoned safety precautions that are relevant to the experiment. In this case it was expected that they would describe a safety precaution relating either to preventing dust particles entering the eye or to avoiding the moving blades of the fan. Most candidates were awarded credit for the safety precaution.

There are four marks available for additional detail. Candidates should be encouraged to write their plans including appropriate detail; often candidates' answers suggested that they did not have sufficient practical experience. Vague responses were not credited. Those candidates who have followed a 'hands on' practical course are generally much better placed to score these additional detail marks. It is essential that candidates' give detail relevant to the experiment in question rather than general 'textbook' rules for working in a laboratory.

Question 2

In this data analysis question, candidates were given data on how the resonant frequency f in an electrical circuit is affected by capacitance C .

- (a) This question was generally answered well.
- (b) A number of candidates lost credit for rounding errors. It is expected that the number of significant figures in calculated quantities should be the same as, or one more than, the number of significant figures in the raw data. In this case, C was given to two significant figures so it was expected that $1/C$ would be given to two or three significant figures. Some candidates did not determine the absolute uncertainties in C correctly.
- (c) (i) Candidates should be advised to ensure that the size of the plotted points is small; large 'blobs' are not awarded credit. Candidates should be encouraged to check points that do not appear to follow the line of best fit. A number of candidates did not construct the error bars accurately, and some candidates plotted vertical error bars.
 - (ii) Some candidates were careless in their drawing of the lines; candidates should be encouraged to use a transparent 30 cm ruler. They should also be encouraged to ensure that there is a balance of points on each side of the line. The worst acceptable straight line should be either the steepest possible line or the shallowest possible line that passes through all the error bars of all the data points used for the line of best fit. The majority of the candidates clearly labelled the lines on their graph; lines not indicated may not be credited. A number of candidates were not awarded credit for their lines since they were not straight. A significant number of candidates did not draw the worst acceptable line sufficiently accurately.
 - (iii) This part was generally answered well; most candidates clearly demonstrated the points they had used to determine the gradient. Some candidates did not use a sensibly-sized triangle for their gradient calculation. A large number of stronger candidates clearly indicated the points that they

used from the line of best fit. Some candidates used their points from the table but did not gain credit because they did not lie on the line of best fit.

To determine the uncertainty in the gradient, candidates were expected to find the difference between the gradient of the line of best fit and the gradient of the worst acceptable line. Again stronger candidates clearly indicated the points that they used from the worst acceptable line. Some candidates were confused by which line was the best and which was the worst.

- (d) Candidates needed to determine a value for L using the gradient. A large number of candidates either omitted the unit or gave wrong units. Candidates were also required to give the absolute uncertainties in the values for L ; acceptable methods are given in the published mark scheme.
- (e) (i) The stronger candidates were able to determine a value of f in the required range and present it to an appropriate number of significant figures.
- (ii) For this question it is essential that candidates show their working. Many candidates did not realise that the percentage uncertainty was half the sum of the percentage uncertainties in the values of L and C . A common mistake was to use $0.1/10$ rather than $1/10$ when determining the maximum/minimum value of f . Appropriate methods to determine the percentage uncertainty are shown in the published mark scheme.

PHYSICS

Paper 9702/53

Planning, Analysis and Evaluation

Key Messages

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

General Comments

All candidates were able to attempt the paper and there was no evidence of time constraints. The majority of the scripts were clearly written. The majority of graphs were well drawn with points and error bars easily identifiable. To gain maximum credit, it is essential that candidates show all of their working clearly; stronger candidates set out their working clearly and there was logical progression within their answers.

It is clear that the stronger 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 practical support booklets which are available from the Teacher Support Site.

Comments on Specific Questions

Question 1

Candidates were required to design a laboratory experiment to investigate how the induced e.m.f. across a coil varies with the thickness of card inserted between the two iron cores in a transformer-like arrangement. Candidates were also required to explain how they would verify the given equation and determine a constant from the measurements. The description of the experiment by candidates has improved. However, some candidates wrote a list of irrelevant points which had been learnt by rote, e.g. temperature, parallax and electrocution.

The initial marks were awarded for correctly identifying the independent and dependent variables. Most candidates correctly realised that the thickness of the card was the independent variable and the induced e.m.f. was the dependent variable.

Further credit is then available for controlling variables: candidates should indicate how a fair test could be made by keeping appropriate variables constant. A significant number of candidates write "control" instead of "constant" for the constant variable and this was not credited. Candidates should also be aware of the difference between a constant and a variable that is to be held constant in the experiment. In this case credit was available for keeping the (peak) current in the primary coil constant. There was also a mark for the additional detail of stating that the frequency of the power supply was kept constant or the number of turns on each coil needed to be kept constant.

Five marks are available for the methods of data collection. Candidates were expected to draw a labelled diagram for this investigation. Diagrams should be realistic, well labelled, and have correct workable

electrical circuits. Many candidates did not draw an acceptable diagram. The primary circuit needed to show a variable a.c. supply or signal generator as well as an ammeter and variable resistor connected to a labelled coil. The secondary circuit required a voltmeter or c.r.o. across the second labelled coil.

To investigate the relationship, candidates needed to indicate how the thickness of card was measured, and micrometers and Vernier calipers were accepted. Credit was also awarded for the additional detail of repeating and averaging the thickness of the card. The final mark in this section was awarded for the method of keeping the current constant. This required both an explanation and a correctly positioned ammeter (with correct symbol) in the circuit diagram.

There are two marks available for the analysis of the data. It was expected that candidates would state the quantities that should be plotted on each axis of a graph for the first mark. Most candidates were successful. The second analysis mark was awarded for explaining the determination of the value of σ . This required σ to be the subject of the formula, i.e. $\sigma = -\text{gradient}$ (not $\text{gradient} = -\sigma$). There was some confusion in explaining the graph when logs to the base 10 (\log or \lg) were used. Where candidates incorrectly suggested plotting $V-t$ graphs, the second analysis mark could not be awarded. Additional detail marks were available for showing the logarithmic equation and for stating that the relationship would be valid if the data points on the graph are linear with a y -intercept equal to $\ln V_0$; some candidates did not state that the line had to be straight.

There was one mark available for describing an appropriate safety precaution. Candidates should be encouraged to give clearly reasoned safety precautions that are relevant to the experiment. In this case it was expected that they would describe a safety precaution relating to the hot coils. Most candidates gained credit for the safety precaution, although a significant number of candidates discussed the iron cores rather than the coils.

There are four marks available for additional detail, and a large number of candidates were able to obtain full credit. Candidates should be encouraged to write their plans including appropriate detail; often candidates' answers suggested that they did not have sufficient practical experience. Vague responses were not credited. Those candidates who have followed a 'hands on' practical course are generally much better placed to score these additional detail marks. It is essential that candidates' give detail relevant to the experiment in question rather than general 'textbook' rules for working in a laboratory.

Question 2

In this data analysis question, candidates were given data on how the final velocity v of a rolling ball is affected by the vertical height h of an inclined board.

- (a) This question was generally answered well.
- (b) Most candidates correctly included the column heading. A number of candidates made rounding errors. It is expected that the number of significant figures in calculated quantities should be the same as, or one more than, the number of significant figures in the raw data. In this case v was given to three significant figures so it was expected that v^2 would be given to three or four significant figures. Some candidates did not work out the absolute uncertainties in v^2 correctly.
- (c) (i) Candidates should be advised to ensure that the size of the plotted points is small; large 'blobs' are not awarded credit. Candidates should be encouraged to check points that do not appear to follow the line of best fit. A small number of candidates did not construct the error bars accurately.
- (ii) Some candidates were careless in their drawing of the lines; candidates should be encouraged to use a transparent 30 cm ruler. They should also be encouraged to ensure that there is a balance of points on each side of the line. The worst acceptable straight line should be either the steepest possible line or the shallowest possible line that passes through all the error bars of all the data points used for the line of best fit. The majority of the candidates clearly labelled the lines on their graph; lines not indicated may not be credited. A number of candidates were not awarded credit for their lines since they were not straight. A significant number of candidates did not draw the worst acceptable line sufficiently accurately.
- (iii) This part was generally answered well; most candidates clearly demonstrated the points they had used to determine the gradient. Some candidates did not use a sensibly-sized triangle for their gradient calculation. A large number of stronger candidates clearly indicated the points that they

used from the line of best fit. Some candidates used their points from the table but did not gain credit because they did not lie on the line of best fit.

To determine the uncertainty in the gradient, candidates were expected to find the difference between the gradient of the line of best fit and the gradient of the worst acceptable line. Again stronger candidates clearly indicated the points that they used from the worst acceptable line. Some candidates were confused by which line was the best and which was the worst.

- (d)(i)** Candidates needed to determine a value for v using the gradient. This was generally answered well, although a small number of candidates determined v^2 or did not use the gradient.
- (ii)** For this question it is essential that candidates show their working. Generally this was answered well, although some candidates did not realise that the percentage uncertainty in the value of v is equal to half the percentage uncertainty in the gradient. Other candidates used the uncertainty 0.05 from the table of v . Appropriate methods are shown in the published mark scheme.
- (e)** Candidates needed to determine a value for K using the gradient. This was generally answered well, although some candidates calculated K to only one significant figure. It was also expected that the value should be within a specified range. Most candidates gave an appropriate unit. A number of candidates did not realise that the absolute uncertainty could not be determined by fractional methods.