PHYSICS

Paper 9702/12
Multiple Choice

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

General comments

When answering numerical questions, it is a good idea to double-check any calculations performed on a calculator, paying careful attention to any prefixes and powers of ten. The spaces on the question paper can be used to carry out the calculations and any other necessary working such as rearranging equations.

It is advisable to read through each question in its entirety before looking at the four possible answers, taking particular care when, for example, a question asks which statement is **not** correct. When a question includes a graph, candidates should check carefully which quantities are plotted on which axes, as these may differ from the 'standard' graphs in some textbooks.

Candidates found **Questions 7**, **10**, **19** and **34** difficult. They found **Questions 3**, **5**, **13**, **21**, **22** and **38** relatively straightforward.

Comments on specific questions

Question 6

Approximately half of the candidates answered this question correctly. Most of the other candidates selected **A** rather than the correct answer **B**, probably forgetting to double the time taken for the ball to reach its greatest height in order to find the total time the ball is in the air.

Question 7

Candidates found this question difficult, with many candidates selecting **B** rather than the correct answer **D**. It is likely that they did not take into account the change in direction of the snooker ball when calculating the change in momentum and hence the average force on the ball. The change in velocity is $21.0\,\mathrm{m\,s^{-1}}$ (not $7.0\,\mathrm{m\,s^{-1}}$) so the change in momentum of the ball is $4.2\,\mathrm{kg\,m\,s^{-1}}$. As the ball is in contact with the cushion for a time of 0.60 s, the rate of change of momentum (the average force) is 4.2 / 0.6 = 7.0 N.

Question 8

Almost as many candidates selected **B** as the correct answer **D**. The gradient of the displacement–time graph must first increase from zero as the tennis ball is accelerating from rest. It eventually becomes constant when the ball is falling at its constant (terminal) velocity. Graphs **A** and **B** can be rejected because their gradients decrease initially.

Question 10

Many candidates found this question difficult, with many selecting graphs **B** or **D** rather than the correct answer **A**. For an oil drop of mass m and charge $+q$ falling at its constant (terminal) speed v_0:

$$qE + kv_0 = mg$$

where k is a constant. Rearranging this equation:

$$v_0 = -\frac{qE}{k} + \frac{mg}{k}.$$

The graph of v_0 against E is a straight line with a negative gradient and a positive y-intercept, which is shown in **A**.

Question 11

The majority of the candidates calculated the magnitude of the torque required to maintain equilibrium correctly. Some chose the wrong direction for the couple needed to maintain equilibrium. The total moment exerted by the weights on the bar is 40 N m anticlockwise. The torque of the couple needed to maintain equilibrium would therefore need to act in the opposite direction, i.e. clockwise.

Question 16

Many candidates thought that **A** (‘Some of the water gains gravitational potential energy’) was the incorrect statement and therefore the answer to the question. The wooden cylinder is submerged in a bath of water. As the wooden cylinder is pushed down, the level of water in the bath would increase and some of the water would gain gravitational potential energy. Statement **A** is therefore a correct statement.

Question 19

Many candidates incorrectly selected **A**. The area under the stretching curve is the work done on the rubber cord during stretching. The area under the contraction curve is the work done by the rubber cord during contraction. Statement **A** would only be true if the stretching and contraction curves were identical. The area between the two curves represents the energy dissipated during the stretching and contraction processes as thermal energy (heat) in the rubber cord.

Question 29

The direction of an electric field is the direction of the force on a unit positive charge. In the question, the force on a negatively charged test charge experiences a force radially away from charge X (to the right) so the direction of the electric field must be towards X (to the left).

Question 34

Candidates found this question difficult. The question states that the terminal potential difference (p.d.) across cell 1 is zero. If the current in the circuit is I:

$$E_1 = Ir_1 \text{ and therefore } I = \frac{E_1}{r_1}.$$

Applying Kirchhoff's second law around the whole circuit:

$$E_1 + E_2 = I(r_1 + r_2 + R) = \frac{E_1}{r_1} \times (r_1 + r_2 + R).$$

Rearranging this equation gives the value of R, which is

$$R = \frac{E_2 r_1 - E_1 r_2}{E_1}.$$

Question 35

Many candidates found this question difficult. Statement **C** explains why the terminal potential difference of the battery V decreases when the current I in the circuit increases. The resistance of the variable resistor is decreased so that the current I increases. The potential difference Ir across the internal resistance (the 'lost volts') must also increase, so the terminal potential difference $V = E - Ir$ decreases.

Question 37

When the galvanometer reads zero, the potential difference across the variable resistor and 2.0 Ω resistor combination must be the same as the e.m.f. of the 2.0 V cell. For the potential divider circuit, if the resistance of R is R, then:

$$\frac{R + 2.0}{R + 2.0 + 10} = \frac{2.0}{6.0}.$$

This gives R = 3.0 Ω, which is answer **A**.

PHYSICS

Paper 9702/22
AS Level Structured Questions

Key messages

- Candidates should read each question carefully before answering. Important instructions may be overlooked if the question is only scanned.
- Definitions and laws must be stated in precise detail. Candidates should choose their wording carefully as an omitted or incorrect key word can affect the meaning of a candidate's response.
- Candidates should pay particular attention to the prefixes of units. If these are ignored or interpreted incorrectly, it can lead to a power-of-ten error in the final answer.
- In 'show that'-type questions, credit is given for showing the calculation as well as the final answer. Therefore, candidates must carefully present each step of the calculation. It is important to remember that when an equation is rearranged, the new subject should also be given.

General comments

The marks awarded varied over a wide range. In general, candidates did not have any difficulty in understanding the questions.

There were certain questions that most candidates found particularly challenging. These included explaining why the air resistance acting on the steel ball may be neglected in **Question 2(b)**, the last part of the question on waves (**Question 5(c)(iv)**), and the last part of the electrical question (**Question 6(c)(iv)**).

There was no evidence of well-prepared candidates lacking time to complete the question paper.

Comments on specific questions

Question 1

(a) The majority of the candidates were able to distinguish between vector and scalar quantities.

(b) (i) Most candidates were able to use the definition of electric field strength to derive its SI base units. Some candidates did not read the question carefully and based their derivations on inappropriate symbol equations that were unrelated to the definition of electric field strength.

(ii) Most answers were correct. The most common mistakes were incorrectly transposing the given equation and assuming that the base units of charge are A s^{-1} (instead of A s).

Question 2

(a) Acceleration was usually defined correctly. A small proportion of the candidates incorrectly defined it as 'the rate of velocity', 'the change of rate of velocity' or 'the rate of change of velocity per unit time'.

(b) (i) Many candidates explained that the air resistance would be small. However, the full explanation involves comparing the magnitude of the air resistance to the weight of the ball. Candidates needed to explain that the air resistance is much less than the weight which means the air resistance is insignificant.

(ii) This question was generally well answered.

(iii) The candidates were able to calculate the answer using one of several different methods. A significant number of the weaker candidates incorrectly assumed that the ball's speed stayed constant (rather than increased) as it moved through the beam. Another common mistake was to calculate the time interval for the ball to accelerate from rest through a distance of 0.080 m, which incorrectly assumes that the ball has zero velocity when it touches the beam.

(c) Most candidates correctly stated that the time interval would be longer with the second ball, but the explanation for this was sometimes omitted or incorrect. Many candidates compared the masses and weights of the two balls, but without explaining how the motion of the second ball would be different to that of the steel ball.

Question 3

(a) When candidates state Newton's third law of motion, as well as stating that the forces are equal and opposite, it should be made clear that the forces act on different objects. Vague and incomplete statements such as 'action and reaction are equal and opposite' should be avoided. Weaker candidates sometimes confused the third law with one of Newton's other laws of motion.

(b) (i) This was a 'show that'-type question. In this type of question, credit is given for showing the calculation as well as the final answer. Candidates must carefully present each step of the calculation. It is important to explicitly state the subject of any equation. When an equation is rearranged, the new subject should also be given.

The expression for the initial total momentum before the collision was usually equated correctly to the expression for the final total momentum after the collision. However, some of the weaker candidates then found it a challenge to do the subsequent algebraic manipulation to obtain the final answer.

(ii) Almost all of the candidates could recall the general expression for kinetic energy. The majority were also able to write down expressions for the total kinetic energy after the collision and the total kinetic energy before the collision. However, many found it a challenge to manipulate the algebra to obtain the final numerical ratio. A common mistake was to calculate the reciprocal of the correct answer.

(iii) This question was generally answered correctly, although candidates sometimes made the mistake of restating their answer to **(b)(ii)**.

(c) (i) Some candidates did not read the question carefully and so described the momentum or velocity of block X instead of the resultant force acting on block X. In **part 1**, some candidates mentioned that the magnitude of the resultant force was constant but without stating that it was zero. In **part 2**, the resultant force was often incorrectly described as decreasing and the direction of the resultant force was often incorrectly described as being in the same direction as the velocity of block X.

(ii) The majority of the candidates drew the graph correctly from 0 to 20 ms. A common mistake was to then draw the graph from 20 ms to 40 ms so that the momentum went up by one big square instead of by four big squares. This may have been due to candidates confusing the momentum–time graph with a velocity–time graph. Most candidates realised that the graph would then be a horizontal line from 40 ms to 60 ms, although the horizontal line was often drawn at the wrong momentum. Almost all the candidates drew their graph lines carefully with a pencil and a ruler.

Question 4

(a) (i) This question was usually answered correctly, although a small proportion of the candidates incorrectly stated that the direction was downwards.

(ii) Many candidates did not realise that the magnitude of the viscous force would increase. Some candidates said that it would decrease. Other candidates attempted to describe the motion of the sphere without mentioning the variation in the magnitude of the viscous force.

(b) (i) The candidates needed to state that for an object in (rotational) equilibrium, the sum of the clockwise moments about a point is equal to the sum of the anticlockwise moments about the same point. Some candidates vaguely referred to clockwise or anticlockwise moments, but not to the sum of those moments. Another common omission was the required reference to a common point or pivot. The weakest candidates sometimes defined the moment of a force instead of stating the principle of moments.

(ii) Some candidates found it difficult to deduce the correct distances of the various forces from pivot C when they were attempting to calculate the individual moments of those forces.

(iii) Most candidates found this question to be challenging. A common error was to develop an equation that contained a non-zero moment due to F_B. Some candidates gave the distance of the man from point C as their final answer instead of converting it to the distance from end D.

Question 5

(a) Although there were many correct statements of what is meant by the wavelength of a progressive wave, some statements needed to be more precise. For instance, it is too vague to state 'the distance from one point to the next similar point'. Some candidates stated that it is 'the distance between two wavefronts' which is also vague as it is not clear which two wavefronts in the wave are being referred to.

(b) Most candidates knew how to calculate the frequency from the time period. Weaker candidates were unable to use the time-base setting and the waveform on the screen of the CRO to calculate the time period. A common incorrect final answer was 400 Hz which is calculated by considering half a cycle rather than a full cycle of the waveform. Some candidates made a power-of-ten error by not converting ms to s.

(c) (i) As this was a 'show that'-type question, it was essential to show clearly the full calculation as well as the final answer. Some candidates obtained the given numerical answer by an incorrect method, which could not be given credit. Others stated in their calculation that distance BC was 19.2 m, but did not show how they had calculated that distance.

(ii) A small proportion of the candidates explained that the path difference was equal to four wavelengths. A greater proportion explained that the waves from the two different paths were meeting in phase so that constructive interference leads to maximum intensity.

(iii) Many candidates understood how the time difference could be calculated from the path distances and the speed of the waves. A common mistake was to guess a value for the speed of the waves rather than to calculate the actual value of the speed.

(iv) The strongest candidates realised that the next intensity maximum is detected when the path difference is equal to three wavelengths. A common wrong answer for the wavelength was 3.2 m which corresponds to the path difference being equal to two wavelengths.

Question 6

(a) Candidates needed to refer to the <u>sum</u> of the current entering a junction being equal to the <u>sum</u> of the current leaving the junction. No credit was given for statements that omitted this important part of the law. Weaker candidates sometimes muddled Kirchhoff's first and second laws and referred to a loop in a circuit rather than a junction.

(b) (i) This question was generally well answered. Weaker candidates sometimes incorrectly assumed that the resistance would be equal to the reciprocal of the gradient of the graph. This assumption only applies if the graph is straight line through the origin which was not the case here. Candidates needed to convert the unit of current from mA to A in order to avoid having a power-of-ten error in their final answer. A small number of candidates did not read the question carefully and calculated the resistance of resistor X rather than that of the diode.

(ii) There were many correct descriptions, although some candidates incorrectly described the resistance as remaining constant or as increasing. A small number of very weak candidates just described how the current varied with potential difference, without making any reference to resistance.

(c) (i) Many candidates seemed to miss the instruction to use Fig. 6.1 to determine the answer. The most common incorrect answers were 0.60 V and 0.30 V which are just the individual potential differences across the diode and resistor X respectively.

(ii) There were two different methods of calculating the answer. Most candidates answered the question by first calculating the current in resistor Y. They then used that current with the potential difference across resistor Y to calculate its resistance. A small proportion of the candidates tried a different method in which they calculated the total external resistance and then used the formula for resistors in parallel to find the resistance of Y. This latter method of calculation is valid but mistakes were often made by candidates attempting this method.

(iii) Almost all candidates were able to state a correct formula for power, although errors were sometimes made when substituting numerical values into the formula.

(iv) A common incorrect answer was 4.5 mA, which would be the current through the diode if it was connected on its own directly across the terminals of the new cell.

Question 7

(a) Many candidates gave a correct answer. A common mistake was to confuse the number of neutrons with the number of nucleons. Some candidates wrote the two answers the wrong way round.

(b) Many candidates were able to convert the units of energy from MeV to J, although sometimes the factor of 10^6 was missing from the conversion. The full calculation proved to be challenging for most candidates.

PHYSICS

Paper 9702/33
Advanced Practical Skills 1

Key messages

- Candidates should be encouraged to set up their graphs to make them easy to work with in later parts of the question, and to check that the scales used are linear. Candidates should be encouraged to use the whole graph grid available.
- Candidates need to use a sharp pencil to plot points and draw lines of best fit. Points should be drawn as neat crosses and not as 'blobs' (circles greater than half a square in diameter), and lines should be continuous, thin and straight. A transparent 30 cm ruler should be used for drawing lines of best fit.
- To be successful answering **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out and relate in turn to the measurements taken. To practise and develop this skill, candidates should be encouraged to look at the experiment chronologically stating the limitations as they encounter them or focus on the difficulties of the measurements that they are asked to collect.

General comments

Most centres did not have any difficulties in providing the equipment required for use by the 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 when marking. No 'extra' equipment should be available to the candidates. In some cases this may disadvantage candidates.

Any help given to a candidate should be noted on the Supervisor's Report. Supervisors are reminded that help should **not** be given with the recording of results, graphical work or analysis. Supervisors are also reminded to submit both a sample set of results and the Supervisor's Report.

The general standard of the work done by the candidates was good, and there were many excellent scripts. Candidates did not seem to be short of time and both questions were attempted by most candidates. They demonstrated good skills in the generation and handling of data but could improve by giving more thought to the analysis and evaluation of experiments.

Comments on specific questions

Question 1

(a) Most candidates stated a value for x in range and with a unit. Some candidates stated a value outside the range or omitted a unit. Many candidates stated y in range. In the cases where y was out of range, credit could still be awarded if the value was close to the Supervisor's value.

(b) Most candidates were able to collect six sets of values of x and y without assistance from the Supervisor. Some candidates collected more results. Very few candidates collected five or fewer.

Many candidates did not extend their range to $x \leq 10.0$ cm and $x \geq 50.0$ cm. Candidates needed to make use of the whole metre rule provided in order to gain credit.

Many candidates were awarded credit for the column headings. A few candidates omitted either the unit or the separating mark for one or both of the columns.

Many candidates correctly recorded their raw values for x and y to the nearest 0.1 cm. Some candidates stated their measurement to the nearest cm e.g. 20 cm without considering that they can make the measurement to the nearest mm using the ruler provided. Some candidates added on a trailing zero to the end of their number if it was less than 10.0 cm to make the number of significant figures the same down the column (e.g. 15.0, 9.00, 5.00 cm). This cannot be awarded credit as the number of decimal places in the raw readings of x must reflect the precision of the ruler (i.e. 15.0 cm and 9.0 cm).

(c) (i) Some candidates omitted labels or marked their scales with large gaps between the labels (more than three large squares). Compressed scales (where the plotted points occupy less than four large squares in the x or less than six large squares in the y direction) were often seen and also did not gain credit. This may have arisen because of the candidate's perceived need to start the graph at the origin. There were many incidences of awkward scales (e.g. based on 3 or 12).

A few weaker candidates set the minimum and maximum reading in the table to be the minimum and maximum of the graph grid, leading to time-consuming work plotting and using the scales. Awkward scales cannot be awarded credit and it was very common for candidates using such scales to make further mistakes with subsequent read-offs.

Some candidates labelled the scale markings with their readings from the table and this cannot gain credit. A few candidates used non-linear scales. Graphs with non-linear scales cannot be given credit either for the axes or for the quality of data if the points are plotted in the part of the scale that is non-linear. Candidates should be encouraged to check their scales for linearity.

Some points were drawn as dots with a diameter greater than half a small square, or were incorrectly plotted so that they were greater than half a small square from the correct location. If a point seems anomalous, candidates should be encouraged to check the plotting and to repeat the measurement if necessary. If such a point is ignored in assessing the line of best fit, the anomalous point should be labelled clearly, e.g. by circling the point. There is no credit specifically for identifying an anomalous point, so candidates should be reminded that they do not need to identify an anomalous point if they do not think they have one.

(ii) Some candidates were able to draw carefully considered lines of best fit. Others joined the first and last points on the graph or any three points on a straight line 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. Many lines needed rotation to get a better fit, or an anomalous point needed to be identified to justify the line drawn. Some candidates were not awarded credit because their lines were kinked in the middle, a double line or drawn freehand without the aid of a ruler.

(iii) Some candidates used a suitably large triangle to calculate the gradient, gaining credit for correct read-offs, and substituted into $\Delta y / \Delta x$. Other candidates needed to check that the read-offs used were within half a small square of the line of best fit and show clearly the substitution into $\Delta y / \Delta x$ (not $\Delta x / \Delta y$). The equation $m(x - x_1) = (y - y_1)$ should be shown with substitution of read-offs.

Candidates need to check that the triangle for calculating the gradient is large enough (the hypotenuse should be greater than half the length of the line drawn). There were many instances of incorrect read-offs, and many candidates would benefit from double-checking their read-offs.

Many candidates were able to correctly read off the y-intercept at $x = 0$ directly from the graph, but a large number of candidates incorrectly read off the y-intercept when there was a false origin. Some candidates correctly substituted a read-off into $y = mx + c$ to determine the y-intercept. Others needed to check that the point chosen (if it was from the table) was on the line drawn.

(d) Most candidates recognised that A was equal to the gradient and B was equal to the intercept calculated in **(c)(iii)**. Some candidates incorrectly stated units for A (e.g. m or cm), omitted a unit for B or used incorrect units.

(e) Stronger candidates substituted their value of A to calculate M correctly. Many candidates did not rearrange the equation correctly. Some candidates did not give their answer to three significant figures.

Question 2

(a) (i) Most candidates measured values of x in range and to the nearest mm. Some candidates incorrectly stated the measurement to the nearest cm or 0.1 mm.

(ii) Many candidates are familiar with the equation for calculating percentage uncertainty and gave an uncertainty in x that was in an appropriate range for this experiment given the inherent difficulties in taking the measurements involved. Some candidates made too small an estimate of the absolute uncertainty in the value of x, typically 1 mm.

Some candidates repeated their readings and correctly gave the uncertainty in x as half the range, although other candidates did not halve the range.

(b) (i) Some candidates stated values of T in range with evidence of repeats of more than one set of oscillations. Many candidates did not repeat sets of oscillations. Candidates should be encouraged to measure multiple (e.g. 3) sets of $5T$ or $10T$.

Candidates must make clear how many oscillations they timed. Some candidates could not be awarded credit because they gave an answer outside the accepted range and no indication of how many oscillations they timed. Some weaker candidates misinterpreted the stop-watch (0:00:63 was read as 63 s). A few candidates confused the period with the frequency and, having found T, proceeded to find f and state this as their final answer for T.

(ii) Many candidates found their second value of T to be greater for the oscillating attracting magnets.

(iii) Many candidates correctly calculated $T_2 - T_1$. Some candidates truncated their answer instead of rounding correctly.

(c) Most candidates recorded second values of x, T_1 and T_2. Many candidates calculated a second value of $T_2 - T_1$ that was smaller in value than their first value, gaining credit for quality.

(d) (i) Most candidates were able to calculate k for the two sets of data, showing their working clearly. A minority of candidates incorrectly rearranged the equation algebraically to calculate $1 / k$, missed out the power of 3 or inadvertently substituted the wrong values.

(ii) Many candidates correctly justified the number of significant figures they had given for the value of k with reference to the number of significant figures used in x and ($T_2 - T_1$). Many candidates gave reference to just 'raw readings' or 'values in calculation' without stating what these values were, related their significant figures to x^3 and not the raw x value, or referred only to T rather than T_2 and T_1.

(iii) The stronger candidates calculated the percentage difference between their two values of k, and then tested it against a specified numerical percentage uncertainty as a criterion, commonly using 10%, 20% or the percentage uncertainty calculated for x. Some candidates omitted a criterion, or gave a general statement such as 'this is valid because the values are close to each other' or 'strongly supported' without any working, which could not be accepted. Occasionally candidates gave a contradictory statement such as 'my results do not support this relationship as my % difference is less than 10%'.

(e) Many candidates recognised that two sets of data were insufficient to draw a valid conclusion and stated an improvement of taking more readings and plotting a graph. Some problems stated by candidates correctly related to the measurements taken with a valid reason, although there were many identified problems that were not linked to the measurements.

Various reasons for difficulty in measuring x were given, such as having to hold the ruler vertically in mid-air or there was parallax error in these measurements. Also commonly seen were limitations relating to the difficulty in aligning the magnets vertically so that the oscillations were in the vertical plane only. To gain credit, the quantity that was difficult to measure should be specified along with the difficulty. Just 'parallax error', 'parallax error while reading values', 'hard to measure distance between the two magnets' or 'difficult to measure x' without further detail cannot be awarded credit. Another reasonable problem was that the values of the $T_2 - T_1$ were short (or there was a large percentage uncertainty in the $T_2 - T_1$ value). There was no credit for stating that the times themselves were too short.

Credit is not given for suggested improvements that could be carried out in the original experiment, such as ‘repeat measurements’, ‘do more readings to get an average value’, ‘look perpendicularly onto the ruler’, etc. Unrealistic solutions were also not given credit, e.g. ‘robotic arm’ or ‘mechanical hand’ to hold and release the magnet. In this particular experiment, attention to an improvement in measuring x (e.g. clamping the ruler) was more important than providing a method to eliminate any forces. Problems that were irrelevant or that could have been removed if the candidate had taken greater care were 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 then encouraged to suggest practical solutions that either improve technique or give more reliable data. Clarity of thought and expression separated the stronger candidates from those less prepared to deal with practical situations and the limitations. Candidates should be encouraged to write about four different problems (perhaps relating to the different measurements undertaken or chronologically going through the experiment) stating <u>how</u> these difficulties impact on the experiment. Candidates should then try to think of associated solutions that address each of these problems.

PHYSICS

Paper 9702/34
Advanced Practical Skills 2

Key messages

- When attempting to measure the period *T* of an oscillating system, it is good practice to record the time taken for a large number *n* of oscillations (e.g. *n* = 5 or 10 complete oscillations) and to repeat this measurement at least two or three times. An accurate value for *T* can then be calculated by finding the mean value of the measurements and then dividing this value by *n*.

- Copying out a table of readings can result in transcription errors, so it is good practice to plan and prepare a table before taking measurements. The table should include columns for any calculated values. Measurements can be recorded in the table as they are taken, and it is not essential that the values are in numerical order. Any values that are not used in further analysis and graphs should be neatly crossed out.

- It is important that a wide range of values is included when taking a series of readings. The maximum range is defined by the physical limits of one or other of the parameters being measured, and the maximum and minimum measurements should be reasonably near to these limits.

- To be successful answering **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out and relate in turn to the measurements taken. To practise and develop this skill, candidates should be encouraged to look at the experiment chronologically stating the limitations as they encounter them or focus on the difficulties of the measurements that they are asked to collect.

General comments

Most centres did not have any difficulties in providing the equipment required for use by the 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 when marking. No 'extra' equipment should be available to the candidates. In some cases this may disadvantage candidates.

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The general standard of the work done by the candidates was good, and there were many excellent scripts. Candidates did not seem to be short of time and both questions were attempted by most candidates. They demonstrated good skills in the generation and handling of data but could improve by giving more thought to the analysis and evaluation of experiments.

Comments on specific questions

Question 1

(a) Almost all candidates recorded a value for *x* in the range 13.0–17.0 cm.

(b) The majority of candidates recorded the time for at least 5 complete oscillations and repeated the measurement at least once in order to find a mean value for *T*.

(c) Almost all candidates were able to record six sets of values of *x* and *T* successfully, showing the correct trend (*T* should increase as *x* increases). A small number of candidates recorded results that showed the wrong trend.

Very few candidates made the best use of the possible range of values of *x*. Candidates needed to try to include the largest and smallest possible values of *x* by including one value for *x* which was less than or equal to 5.0 cm and one value of *x* that was more than or equal to 20.0 cm.

Most candidates labelled their table of results correctly by including a quantity and a unit (where appropriate) for each column heading. The quantity and the unit should be separated by a solidus or with the units in brackets e.g. *x* / cm or *x* (cm).

Most candidates recorded all their raw values of *x* to the nearest mm, though some only recorded their raw values for *x* to the nearest cm. A small number of candidates added an extra zero to all their values (e.g. 2.00 cm) to give the false impression of greater accuracy in their measurements. For 'static' measurements, such as *x* in this experiment, there is no merit in repeating the measurement, since the measurement does not change. Each measurement need only be made and recorded, carefully, once.

The majority of candidates calculated and recorded their values for x^2 and T^2 correctly, and to an appropriate number of significant figures.

(d) (i) Candidates were required to plot a graph of T^2 on the *y*-axis against x^2 on the *x*-axis. Most gained credit for drawing appropriate axes, with labels and sensible scales.

A few candidates made things difficult for themselves by choosing extremely awkward scales, making the correct plotting of points much more demanding. Some chose the highest and lowest values in their tables as the lowest and highest points on their graph scales and then calculated intermediate values. Although this appears to make the maximum use of the graph grid, it invariably makes it very difficult to plot all the points correctly. This type of scale cannot be given credit for the axes, and these candidates often made further mistakes with incorrect read-offs when calculating the gradient or the *y*-intercept of the line.

A few candidates chose non-linear scales, or scales which meant that one or more points were off the graph grid.

Most candidates gained credit for plotting their tabulated readings correctly. If a point seems anomalous, candidates should repeat the measurement to check if an error in recording the values has not been made. If such a point is ignored in drawing the line of best fit, the anomalous point should be labelled clearly, e.g. by circling the point.

Most candidates plotted their points on the graph paper carefully; 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 but clear pencil cross, or a point with a circle, is recommended).

The majority of candidates achieved credit for the quality of their data.

(ii) Many candidates were able to draw a straight line which was a good fit to the points plotted, with a reasonable distribution of points above and below the line. Weaker candidates often tended to join the first and last points on the graph, regardless of the distribution of the other points, or draw a line which could clearly be improved by rotation. A few candidates drew a double line, or a line with a 'kink' in it.

(iii) Most candidates used a suitably large triangle to calculate the gradient, gaining credit for correct read-offs, and substituted into $\Delta y / \Delta x$. Other candidates needed to check that the read-offs used were within half a small square of the line of best fit and show clearly the substitution into $\Delta y / \Delta x$ (not $\Delta x / \Delta y$). The equation $m(x - x_1) = (y - y_1)$ should be shown with substitution of read-offs.

Candidates need to 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 were not awarded credit because they selected one or both data points from the table of results which did not lie on the line of best fit.

It is important that candidates show their working, making it clear which points they have chosen for the read-offs e.g. by drawing the triangle on the graph.

Several candidates were able to read the value of the intercept directly from the graph as their scale on the *x*-axis started at zero. Others correctly substituted a read-off into $y = mx + c$ to determine the *y*-intercept. As with the gradient calculation, a point from the table can only be used if it lies on the line of best fit.

(e) 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 **(d)(iii)**.

The majority of the candidates recorded correct units for *a* (e.g. $s^2\,cm^{-2}$) and *b* (s^2); others omitted the units for *a* or *b* or both quantities. The units for *a* and *b* can be derived directly from the quantities plotted on the graph and confirmed by the equation given in **(e)**.

(f) Candidates were asked to calculate a value for the acceleration of free fall *g*. Most candidates did this successfully. A common mistake was to measure the diameter of the beaker but then not halve the value to find *R*.

Question 2

(a) Most candidates measured and recorded the value of *h* in the appropriate range and to the nearest mm. Some candidates recorded their (raw) value(s) to the nearest 0.1 mm, an unjustifiable degree of precision using a metre rule or a 30 cm ruler; others forgot to convert their value from cm to mm on the answer line.

(b) Almost all candidates were able to record a value for *F* to the nearest 0.1 N and within the appropriate range.

(c) (i) Candidates needed to show that they had measured the diameter of one of the larger slotted masses and calculated the radius by halving their value. Some candidates attempted to measure the radius directly, or did not show enough working to indicate they had halved the diameter, so were not awarded credit.

(ii) Most candidates calculated the value of α from the equation given in the question, though a few candidates either rounded their answer on the answer line incorrectly, or gave the value of $(r - h)/r$ rather than $\sin^{-1}(r - h)/r$.

(iii) Candidates were asked to justify the number of significant figures given for their values of α. Some correctly linked the significant figures of α to the significant figures of $(r - h)$ and *r* (or simply, *r* and *h*); others only referred to the 'raw data' and this was not specific enough for credit to be awarded.

(d) Most candidates recorded raw value(s) for *F* to the nearest 0.1 N, with a unit. A few candidates either expressed their value(s) of *F* to the nearest newton, or omitted units from their answer.

The majority of candidates repeated the measurement two or three times to find an average value for *F*.

(e) Candidates were asked to estimate the percentage uncertainty in their value of *F*. Most were familiar with the equation for calculating percentage uncertainties, but some candidates underestimated the absolute uncertainty in the value of *F*. A realistic estimate for the absolute uncertainty in the measurement of the value of *F* is in the range 0.1–0.4 N.

(f) Almost all candidates recorded second values of *W*, *r* and *F*. Most candidates were also awarded credit for the quality of their data.

(g) (i) Most candidates were able to calculate the two values for *k* correctly. Some weaker candidates were not awarded credit as they calculated $1/k$.

(ii) Candidates were asked to explain whether their results supported a suggested relationship – in other words, allowing for the uncertainties in the measurements, whether the two values of *k* could be regarded as equal. To do this, candidates need to test the hypothesis against a specified numerical percentage uncertainty, either taken from **(e)** or estimated themselves.

Where candidates state a percentage uncertainty value, it is a good idea to try to justify this value in some way, particularly if a very large percentage uncertainty is suggested.

Most candidates were able to calculate the percentage difference between the two values of *k*, and then compare this difference to an estimated overall uncertainty for the experiment (e.g. 20%). Some candidates gave answers such as 'the difference between the two *k* values is very large/quite small' which is insufficient. A numerical percentage comparison is needed.

(h) Many candidates recognised that two sets of data were insufficient to draw a valid conclusion, though some confused conclusions with results.

In this experiment, the main difficulties included large percentage uncertainties in the measured values of *h* and *F* (as both are small) and measuring *F* accurately with the newton meter. Pulling the newton meter horizontally was also difficult and the two sizes of slotted masses tended to be pulled at different angles to each other.

Some candidates simply described measurements that were difficult to make without explaining why they were difficult e.g. 'it was difficult to measure *F*'. A reason for the difficulty is also needed to gain credit, e.g. 'it was difficult to measure *F* accurately because the reading on the newton meter suddenly falls to zero when the masses start to move'.

Generic answers such as 'parallax error' or 'systematic error', on their own, do not receive credit; they must be justified by further explanation.

Valid improvements included taking more readings for different sized slotted masses and then plotting a suitable graph to test the suggested relationship. Some candidates suggested calculating further values for *k* and then calculating an average value, implying that *k* is constant. They should instead state that the values of *k* should be compared with each other to see whether *k* being constant is a valid conclusion.

The key to this section is for candidates to identify genuine problems associated with setting up this experiment and in obtaining readings. Candidates are then encouraged to suggest practical solutions that either improve technique or give more reliable data. Clarity of thought and expression separated the stronger candidates from those less prepared to deal with practical situations and the limitations. Candidates should be encouraged to write about four different problems (perhaps relating to the different measurements undertaken or chronologically going through the experiment) stating <u>how</u> these difficulties impact on the experiment. Candidates should then try to think of associated solutions that address each of these problems.

PHYSICS

Paper 9702/42
A Level Structured Questions

Key messages

- It is important that candidates use technical language accurately. Examples of words that are often confused by candidates are atom and molecule, nuclide and nucleus, and force and field. Candidates are not able to obtain full credit if they use an inappropriate word that makes the response technically incorrect.

- In defining quantities, candidates need to take care to ensure that the definition they give is dimensionally correct. This often requires use of the phrase 'per unit' where the quantity being defined is the ratio between two other quantities, or 'product' where the quantity being defined is two other quantities being multiplied together.

- Candidates need to take care to ensure that they read the question properly, understand what is being asked and give responses that answer the question that is asked. It is not uncommon to find candidates giving answers to questions that were not asked, but that have been asked in recent past papers. Candidates should be advised not to rely heavily on memorising previous mark schemes.

- When answering questions involving calculations, it is important for candidates to show their reasoning clearly. This includes taking care to use the correct conventional symbols for physical quantities. If working is clear and based on use of correct physics, it is often possible for examiners to award partial credit even when the final answer is incorrect. Incorrect answers that are not supported by working cannot be awarded credit.

- Answers to numerical questions should be given to an appropriate number of significant figures; the precision of the data provided in the question is generally indicative of the appropriate number of significant figures for an answer. When performing intermediate calculations within a question, candidates should take care to avoid premature rounding; as a general rule, any intermediate calculated values should always carry at least one more significant figure than will be used in the final answer. Candidates should be made aware that giving answers to an inappropriate number of significant figures, or that are inaccurate as a result of rounding intermediate values prematurely, can both lead to full credit not being awarded.

General comments

The question paper contained questions of a variety of levels of difficulty, enabling candidates at different levels of ability to show what they know. Candidates who knew the 'bookwork', read the questions carefully, took care over their use of technical language and answered the questions asked were able to perform well.

There was no evidence that candidates who were properly prepared for the examination had insufficient time in which to complete the paper. However, it was not uncommon for candidates to omit the occasional part-question. Candidates should be advised that it is always worth offering a response to each part-question; no credit can be obtained where a question has been omitted, but if a response is attempted then it may be possible to award partial credit.

Comments on specific questions

Question 1

(a) This question was generally well answered. Most candidates were able to state the proportionality relationships that govern the gravitational force between point masses. The common mistakes were omission of the reference to point masses, not making the product of the masses clear, and not making any reference to force.

(b) The starting point that candidates were asked to use in deducing the expression for *k* was Newton's law of gravitation. Candidates were expected to equate this expression with the expression for the centripetal force that causes the circular motion of the planet. Candidates who explained that this was what they were doing, and who then correctly worked the algebra through to arrive at the expression for *k*, were awarded full credit. Use of Kepler's law as the starting point did not answer the question.

(c) Most candidates were able to substitute the values given for *R* and *T* and to rearrange the expression to give a value for *M*. There were various common reasons for marks not being awarded, including mistakes with the powers, not converting *T* into seconds, and giving an answer to fewer significant figures than were appropriate.

Question 2

(a) (i) Many candidates appeared not to be familiar with Brownian motion and perhaps had not seen it. This question simply asked candidates to describe what is seen. All that was expected was a description of specks of light moving haphazardly. Many candidates were aware that these specks of light were smoke particles (from which the illuminating light is being reflected), but then added inappropriate suggestions that the particles are seen colliding with each other or with the walls of the container.

(ii) Responses to this question often contained inaccurate use of technical terms. In particular, the words 'particle' and 'molecule' could not be used interchangeably, because in this context one word refers to the smoke particles and the other to the gas molecules. Many candidates were able to articulate that the gas molecules moving around randomly collide with the smoke particles. Only a small number of candidates explained that it is these collisions that cause the motion of the smoke particles described in **(a)(i)**. A common misconception was that the kinetic theory of gases applied to the motion of the smoke particles.

(b) (i) This question was generally well answered, although a significant minority of candidates ignored the instruction to give the answer to three significant figures. A small number of candidates calculated two values for *n* (one from each set of data), and then incorrectly subtracted them to get their final answer.

(ii) Stronger candidates realised that this question simply required multiplication of the molar heat capacity by the number of moles and the temperature rise. Many candidates omitted one or other of these factors.

(c) (i) Candidates were expected to realise that the change is at constant volume and that therefore there is no work done on (or by) the gas. There were many attempts by weaker candidates to calculate non-zero values.

(ii) The omission rate for this question was high. Of the candidates who attempted an answer, many did not use their values for work and thermal energy, instead attempting to calculate something different. Many candidates also misunderstood the 'direction' aspect of the question, and attempted to give indications of a vector direction instead of appreciating that energy changes can only be increases or decreases.

Question 3

(a) The concept of latent heat was generally well known. However, the 'specific' aspect of the definition (requiring 'per unit mass') was less successfully articulated. Candidates need to give dimensionally accurate definitions (with the ratio *energy* / *mass* being clear), and should not conflate quantities and units. Some weaker candidates gave attempted definitions of specific heat capacity rather than specific latent heat.

(b) (i) This was generally well answered, with most candidates able to correctly deduce the answer from the graph.

(ii) Most candidates found this question difficult. Responses in terms of the power of the heater were common, as were those suggesting that the ice was in thermal equilibrium with the surroundings. The best answers discussed the constant difference in temperature between the ice and the surroundings.

(iii) Many candidates were able to indicate (either explicitly or by implication from their use of the data) the correct starting equation linking the energy supplied by the heater and the energy absorbed by the ice. Many candidates were unable to progress further. A variety of incorrect approaches was seen, including adding the data for the two regions together or obtaining different values for specific latent heat from the two regions of the graph and then attempting to combine them in some way. Of the candidates who did realise that they needed to incorporate a common heat loss factor into the equations for the two regions, and then eliminate this component by subtracting the equations, the common mistakes were to use inconsistent times, to forget to convert the time from minutes to seconds, and to unnecessarily convert the masses into kg.

(iv) Most candidates found this question difficult. Of those who did answer **(b)(iii)** successfully, many did not appreciate the need to use the calculated value of L with the energy conservation equation for one of the regions to calculate the term that was eliminated. Responses that only calculated either the rate of energy supply to the ice or the difference in electrical power supplied in the two regions were common.

Question 4

(a) (i) The meaning of damping as the loss of energy of the oscillating system due to resistive forces was not well known. Many candidates discussed the decrease in amplitude (which could receive credit in **(a)(ii)**) as the meaning of damping.

(ii) This question was well answered by most candidates.

(b) (i) Most candidates knew the relationship between angular frequency and period, and were able to deuce the correct period from the graph and use it correctly to calculate ω.

(ii) Many candidates were able to deduce that $2k/M$ is equivalent to the ω^2 term in the s.h.m. equation and to use the value of ω appropriately to calculate k. Some candidates made hard work for themselves by putting in values of a and x; such an approach still leads to the correct answer if carried out correctly, but it involves more opportunity for a mistake to be made.

(c) (i) Variation of amplitude of oscillation with driving frequency was not well understood in general. Many straight lines in various orientations were seen. Of the stronger candidates who did realise that the graph is a curve with a peak at 1.0ω, some curves leading up to the peak were the incorrect shape or insufficient care was taken over the position of the peak.

(ii) Candidates who did not draw graphs of the correct shape in **(c)(i)** found it difficult to obtain credit. Some candidates experienced difficulty in correctly using the word 'amplitude' in this context, because the line of the graph gives different amplitudes at every frequency. Just writing that 'the amplitude is lower' was too vague for credit to be awarded.

Question 5

(a) (i) The definition of specific acoustic impedance was generally well known. Some candidates did not correctly identify that the speed is the speed of the ultrasound in the medium.

(ii) The main difficulty that candidates experienced in answering this question was the conversion of the density to SI units. Many responses were seen that gave an answer to an incorrect power of ten.

(b) Most candidates used the expression for α to correctly calculate the proportion of the ultrasound that is reflected at the boundary. Many candidates ignored that the question was asking for the transmitted intensity fraction and stopped at that point.

(c) (i) The meaning of attenuation as loss of intensity of a wave was generally well known, but many candidates stopped short of relating this loss to the process of the wave propagating through a medium. Many candidates who did discuss the context for the loss of intensity wrote instead about reflection from, or transmission across, boundaries between different media.

(ii) This question was generally well answered by candidates who knew the exponential attenuation equation. Some candidates did not realise that, because the values of μ and the thicknesses are already in compatible units, there was no need to do any unit conversions.

(d) Most candidates found this question difficult. Various permutations of combining the previous answers were seen. Candidates were expected to realise that the cumulative effects of linear attenuation through the fat, absorption at the fat/muscle boundary, and linear attenuation through the muscle, required the product of the answer to **(b)** and the two values in **(c)(ii)**.

Question 6

(a) Many candidates were able to deduce from Fig. 6.1 that the period of the carrier wave is 5 μs and that, therefore, its frequency is 200 kHz. A common incorrect answer was 10 kHz, and a variety of incorrect powers of ten were also seen in candidates' answers.

(b) Only a small number of candidates knew the frequency spectrum for amplitude modulation. Some candidates gave the frequency spectrum for frequency modulation instead, but most incorrect answers were high-frequency sinusoidal curves. Most candidates who knew that the correct answer consists of three vertical lines were awarded credit for drawing them with the correct spacing and the correct relative lengths. Only a minority of these candidates correctly annotated the frequencies to which the lines correspond.

Question 7

Most candidates were awarded at least partial credit for this question. For full credit, candidates needed to convey that CT scanning involves the use of X-rays to scan the object (being investigated) in sections, from many angles, and the images of all the many sections are compiled to form a three-dimensional image of the structure. Some candidates answered a different question from the one that was asked, and wrote about either ultrasound scanning or magnetic resonance imaging.

Question 8

(a) Many candidates only answered one of the two parts of this question. Of those who attempted to give the magnitude, most know that the magnitude is given by $F = Bqv$.

Responses from those that gave the direction were varied, but most realised that the direction was to the right and were able to articulate that in one of the ways accepted by the mark scheme. Some candidates who attempted to give the direction by reference to the letters on the diagram found it difficult to convey clearly enough that the direction is to the right. Other candidates wrote about the direction of movement of the electrons rather than the direction of the force acting on them.

(b) (i) Many candidates correctly identified faces PSHE and QRFG.

(ii) Many candidates also correctly identified one of PE, QF, RG or SH.

(c) (i) Many candidates found it difficult to know where to start with this question. A variety of different valid starting points was accepted, including deducing the number of moles of aluminium in unit volume or deducing the mass (in kg) of one aluminium atom. Many of the stronger candidates were able to go on to demonstrate how the figure of 6.0×10^{28} follows from their starting point. As always, it is important with this type of question to explain reasoning carefully, set it out logically, and use units correctly.

(ii) Most candidates who know that the charge on the charge carriers is the elementary charge were able to substitute the correct numbers into the given equation and calculate the answer correctly. Some missed the unit conversion in the thickness, and some calculated the answer to an insufficient number of significant figures, but otherwise this question was generally well answered.

Question 9

(a) Candidates were expected to define electric potential as the work done per unit charge in moving positive charge from infinity to the point. The 'magnitude' mark required the dimensionally correct ratio (*work / charge*), and the 'sign' mark required the correct direction of work done in relation to the sign of the charge and the direction in which the charge is moved. Credit for both points was achieved only by a relatively small number of candidates.

(b) (i) Many candidates were able to successfully convert 4.8 MeV to J, although some made a mistake with the power of ten represented by the mega prefix. A significant number of the weaker candidates attempted to answer the question using $E_k = \frac{1}{2}mv^2$.

(ii) Most candidates found this question difficult, and a variety of mistakes were seen in the approaches attempted. Some candidates did realise that equating the formula for the potential energy stored between two point charges with the answer to **(b)(i)** is the starting point, but then found it difficult to deduce correctly the charges on the α-particle and the gold nucleus. Candidates who got this far usually went on to calculate a correct answer.

(c) Candidates were expected to comment that the value of *d* calculated in **(b)(ii)** represented an estimate of the upper limit of the size of the gold nucleus. Credit was given for correct discussion based on incorrect answers to **(b)(ii)** provided the answer to **(b)(ii)** was reasonable.

Candidates should have an appreciation of reasonable magnitudes of the quantities involved in the syllabus. As such, they should realise that a value of, for example, 10^5 m for the diameter of a nucleus cannot be correct, and this can be a useful prompt to re-check the working.

Question 10

(a) Most candidates gave responses that could be awarded at least partial credit. For full credit, candidates were expected to convey that, when temperature increases, electrons in the valence band gain energy and jump to the conduction band. This leaves holes in the valence band, and the increase in number density of charge carriers results in a decrease in resistance.

(b) (i) Most candidates found this question difficult, and many did not make a successful start. They were expected to realise that, at the switching temperature, the potentials at the two inputs are equal. Use of the potential divider relationship applied to the two inputs then leads to the value of R_T being 2.2 kΩ at the switching temperature, which can then be read off the graph of Fig 10.2 as being 14 °C. Confusion between the potential differences across the upper and lower parts of the potential divider was a common problem. For example, the p.d. across R_T being equated with the p.d. across the 1.20 kΩ resistor was common, as was equating the p.d. across the 1.50 kΩ resistor with the p.d. across the 1.76 kΩ resistor.

(ii) Candidates were expected to reason that, for the diode to emit light, the output of the op-amp needs to be negative. This requires the potential at the inverting input to be higher than the potential at the non-inverting input. This, in turn, requires a decreased value of R_T and hence a higher value of temperature. Only a small number of candidates gave responses that could be awarded full credit, with each of the marking points proving problematic in different ways. Many responses did not clearly make reference to the output, many discussed changes to V^- without making clear the comparison with V^+, and many came to a correct conclusion about the temperature being above the value in **(b)(i)** but did not explain it by reference to the decrease in R_T.

Question 11

(a) Faraday's law was well known, and most candidates answered this question correctly.

(b) Many candidates answered **(i)** and **(ii)** the wrong way round. These candidates appeared to either think the question was asking about current rather than induced e.m.f. or that the induced e.m.f. varies in proportion to the current in the solenoid. Many candidates, including stronger candidates, did not seem to be aware that the induced e.m.f. depends on the rate of change of current in the solenoid.

(c) Many candidates used the correct starting equation, although few candidates arrived at the correct final answer. Among the stronger candidates, mistakes included forgetting the $\times 2$ factor (to reflect the fact that the current is reversing), forgetting to convert the time to SI units, and using the diameter instead of the radius when calculating the cross-sectional area of the solenoid. More serious mistakes by weaker candidates were the omission of the current in calculating the magnetic flux density and using the diameter of the solenoid as its cross-sectional area.

Question 12

(a) (i) Candidates found it difficult to explain the meaning of random decay. Common incorrect responses were those that either just restated the question or conflated randomness with spontaneity.

(ii) The definition of decay constant as the probability of decay of a nucleus per unit time was correctly given by many candidates. Some thought that the identity of decay constant as activity per unit time or as $\ln 2 / t_{½}$ represented its definition. Others gave a definition of activity rather than decay constant.

(b) This was a challenging question. The mark scheme was structured to enable partial credit to be accessible in a variety of different ways. The question asks for the ratio for 1.00 m^3 of air, but working through the calculations for a volume of 4.80×10^{-3} m^3 was an equally valid approach and was given full credit. The common mistake in pulling together the data for the final answer was using the number of air molecules in one of these volumes and the number of radon atoms in the other volume.

At some point during the calculation there was also a need for candidates to convert the decay constant into SI units, and this proved to be a source of error for many candidates (with many either leaving the decay constant in $hour^{-1}$ or attempting the conversion by multiplying by 3600 rather than dividing). Despite the challenges of the question, however, many of the stronger candidates were awarded full credit.

PHYSICS

Paper 9702/52
Planning, Analysis and Evaluation

Key messages

- In **Question 1**, candidates' responses should include detailed explanations of experimental procedures such as how to control variables, how to take measurements and how to analyse the data.
- Graphical work should be carefully attempted and checked. 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. A full understanding of significant figures and the treatment of uncertainties is required.
- The practical skills required for this paper should be developed and practised with a 'hands-on' approach throughout the course.

General comments

In **Question 1**, it is advisable that candidates should think carefully about the experiment following the points given on the question paper and to imagine how they would perform the experiment in the laboratory. Planning a few key points before answering **Question 1** is useful. Some candidates drew diagrams which did not have enough labels and often some important measurements were omitted. Many candidates were successful in the analysis section with clear identification of how the constant could be determined. It is essential for candidates to have experienced practical work in preparation for answering this paper.

In **Question 2**, candidates should be familiar with completing a results table for quantities and their uncertainty, and with finding the gradient of a graph. For several candidates, credit was not awarded because the points were not plotted correctly, the line of best fit or worst acceptable line was not drawn correctly or coordinates were wrongly read off.

To be successful, candidates should be advised that mathematical working in the latter parts of the question requires a clear statement of the equation used with correct substitution of numbers, and the answer calculated including the correct power of ten. Candidates should set out their working in a logical and readable manner. Care should be taken when numbers are crossed out.

Comments on specific questions

Question 1

Many candidates correctly identified the independent and dependent variables. Candidates should be encouraged then to consider the control of variables and to explicitly state the quantities that need to be kept constant to make the experiment a fair test – in this case the spring constant k and the radius r of the ball needed to be kept constant. A number of candidates use the incorrect term 'control' rather than stating that k and r needed to be kept constant. Candidates should identify the variables to be controlled from the given relationship. Some candidates produced a list of quantities which were not relevant to the equation or not appropriate including environmental conditions such as temperature and pressure of the surroundings.

Candidates were awarded credit for a clearly labelled diagram. Diagrams should be drawn of the workable setup of the experiment. In this experiment, candidates needed to show clearly a spring with the final position of the ball and a method of measuring h e.g. a vertical metre rule. Both the spring and the ball needed to be labelled. Further credit was awarded for the method of attaching the spring to the bench, for clamping the metre rule and for clearly showing the position of a set square on a bench or horizontal surface.

Most candidates gained credit for suggesting using calipers or a micrometer screw gauge to measure the diameter of the ball. Some candidates referred to using these instruments to measure radius, although this cannot accurately be measured directly. Stronger candidates suggested repeating the measurements of the diameter in different directions and then finding the mean.

Candidates needed to explain the method to determine x. It was expected that an appropriate measuring instrument would be chosen, e.g. a rule, then an original position of the spring would be recorded from the rule, and then a compressed position would be recorded with the difference being x. Some candidates incorrectly stated that x was the compressed length of the spring.

Candidates needed to describe a method to determine h. It would be easier to read the position of the ball at the top of its path from the top of the ball or the bottom of the ball. Before the ball is released, it would be more accurate to read the position of the top of the ball owing to the difficulty in determining the location of the centre of the ball. Some candidates suggested placing a mark on the centre of the ball without realising that the ball may not stay in the same orientation as it rises.

Many candidates suggested correct axes for a graph (often h against x^2). A significant number of candidates incorrectly suggested plotting h against x. Candidates must explicitly state the quantities to be plotted on each axis either in the text or on drawn axes – credit is not given for just writing $y = mx + c$ under an expression. Having suggested an appropriate graph, candidates needed to explain how the graph would confirm the suggested relationship. Candidates need to use the words 'relationship is valid if' and the word 'straight' to describe the line. Candidates needed to explain how they would determine a value of ρ from the experimental results. Some candidates correctly identified a relationship between ρ and the gradient but did not make ρ the subject of the equation. Some candidates suggested other graphs to plot such as x^2 against h; these could be given credit if the reasoning was correct and the equation for K was correct. Similarly, some candidates suggested plotting lg h against lg x and this could also gain credit if the gradient and intercept were correctly identified.

The additional detail section had a maximum of six marks that could be awarded. Candidates should be encouraged to write their plans including appropriate detail; some candidates' answers suggested that they did not have sufficient practical experience. Vague responses were not credited. It is essential that candidates' answers are relevant to the experiment in question rather than general 'textbook' rules for working in the laboratory.

In this experiment, a 'light plastic ball' was used. Credit could be awarded for describing a method to prevent the ball rolling on the floor as a trip hazard or for describing how draughts could be avoided. Stating 'do the experiment in a closed room' was not sufficient detail.

Credit was available for describing in detail the use of a video camera. To be awarded credit, candidates needed to show the position of the video camera appropriately in the diagram so that the position of the ball at the top of its path was clearly being recorded, and also to say that the video was played back frame by frame.

Question 2

(a) Candidates who were mathematically confident were able to work through the algebra and achieve credit. Weaker candidates should be encouraged to use the white space on the question paper to rearrange the equation into an equation of a straight line.

(b) Completing the table appeared to be challenging for candidates. Most candidates were able to calculate values for R but often did not use an appropriate number of significant figures. Since values of V and I were recorded to two significant figures, values of R should have been recorded to two (or three) significant figures. Many candidates did not determine the absolute uncertainty in R correctly.

Candidates were then required to determine lg R. Since values of V and I were recorded to two significant figures, lg R should have been recorded to two (or three) decimal places.

The final part of this question was to determine the absolute uncertainty in lg *R*. Candidates need to understand the rules for combining uncertainties, including the conversion from an absolute uncertainty to a percentage uncertainty and the conversion from a percentage uncertainty to an absolute uncertainty.

(c) (i) The points and error bars were straightforward to plot. A significant number of candidates drew large blobs for the plotted points which could not be awarded credit – the diameter of each point should be less than half a small square. Candidates need to take greater care over the accuracy of the error bars and ensure that the error bars are symmetrical.

(ii) Most candidates appear to be using a sharp pencil and a transparent 30 cm ruler which covers all of the points. The line of best fit does not pass through both the highest and lowest point for these data. The worst acceptable line was drawn well in general, and many stronger candidates drew a line which passed through all error bars. Candidates should clearly indicate the lines drawn. Where a dashed line is used to represent the worst acceptable line, the dashed parts of the line should cross the error bars.

(iii) Most candidates clearly demonstrated the points that they used to calculate the gradient. Some candidates misread coordinates or did not use a sensibly sized triangle. A small number of candidates chose data points that did not lie on the lines, often using data from the table that is close to the line instead. Candidates should be encouraged to select two points which are easy to read from the graph. For these data the gradient was negative.

When determining the uncertainty in the gradient, candidates need to show their working including the coordinates that they have used from the worst acceptable line. In calculating the absolute uncertainty in the gradient, there must be evidence of subtraction between the gradient of the line of best fit and the gradient of the worst acceptable line.

(iv) The majority of the candidates who were awarded full credit set out their working clearly. Stronger candidates often substituted a data point from the gradient calculation **(c)(iii)** into $y = mx + c$. A significant number of candidates incorrectly gave the *y*-intercept as the value of lg *R* when lg *T* = 2.48, i.e. these candidates had not understood that there was a false origin.

(d) Candidates must clearly show how the *y*-intercept is used to determine *p*. Credit is not given for substituting data vales from the table into the expression. Some candidates incorrectly used ‘e’. The value of *q* should have been the same as the answer to **(c)(iii)**.

(e) Candidates needed to show clear and logical working for this question. Clear substitution of numbers into equations was needed to determine *T*. Many candidates did not understand that the constants *p* and *q* were valid for *R* values measured in kΩ, i.e. no conversion to Ω was needed.