PHYSICS

Paper 9702/11
Multiple Choice

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

General comments

Candidates should be reminded to read the whole question before attempting to give an answer. The information in full should be used to complete a calculation or draw a conclusion. It is important that candidates read the question carefully and that they are sure that the answer chosen is correctly related to the question.

Candidates found **Questions 5**, **20**, **24**, **33, 36** and **37** difficult. They found **Questions 1**, **14**, **22**, **30**, **34**, and **40** to be relatively easy.

Comments on specific questions

Question 1

Many candidates seemed to give the answer that confused an estimate for diameter with that of radius. Equating the two ratios gives a value close to the radius for a tennis ball, which was answer **D**.

Question 2

Many candidates found it difficult to deal with the powers for the base units of m and s, which made **A** a common incorrect answer. This generally occurs when powers are cancelled incorrectly when the base units are written in both the numerator and denominator.

Question 5

Many candidates made an estimate in the uncertainty that used only used the fluctuation in the reading, and did not consider the ±1%.

Question 7

A significant number of candidates used the mass per unit time as 90 kg per minute without converting to $kg\,s^{-1}$.

Question 8

Weaker candidates often considered the acceleration to be greater as the ball was falling and gave **B** rather than the correct answer **C**. The air resistance and the gravitational force are in the same direction only when the ball is rising.

Question 12

A significant number of candidates chose **B** or **C** rather than the correct answer **A**. All three arrows showing the direction of the forces should show the head of one vector arrow meeting the tail of the next vector arrow when the system is in equilibrium. The weight of the ladder should be vertically downwards.

Question 13

Many candidates gave the incorrect answer **B**. The pressure of the air inside the tube is the same as the pressure of the liquid at a depth of 50 cm.

Question 18

A common incorrect answer was **D**. The effect of doubling the diameter is to give four times the cross-sectional area, and this causes a greater effect on the resulting extension than doubling the tension.

Question 20

Candidates found this question difficult. The rod deforms elastically until it reaches the elastic limit, so only the area beyond P relates to plastic deformation. The correct area is between the curve and the *y*-axis, giving answer **C**.

Question 24

The formula for the Doppler effect is given on page 3. Candidates need to take care to equate the values in the question with the correct quantities in the formula.

Question 29

A significant number of candidates gave the correct answer **C**. There were a number of incorrect answers that used the wrong order for the smallest wavelength. The two waves overlap with the smallest order (2nd) for the longest wavelength and the largest order (3rd) for the smallest wavelength.

Question 33

The relevant equation is on page 3. Candidates needed to substitute the change in current and change in cross-sectional area into this equation to determine the effect on the drift velocity.

Question 36

The two resistors connected in parallel give a reduced circuit resistance when switch S is closed, and therefore a greater circuit current. Many candidates did not realise that this would increase the ‘lost volts’ in the battery and hence give a reduced terminal potential difference.

Question 37

Many candidates chose the incorrect answers **B** and **C**. Candidates should be reminded that the potential difference between two points in a circuit is the same whichever route is taken. In this question, the potential difference between the two circuit connections (‘blobs’) is the same going via the 4.1 V and 3.7 V route or going via the right-hand branch, which means that $4.1 + 3.7 = 2.2 + 1.2 + V_R$.

Question 38

Many candidates chose either **A** or **B**. The potential difference across the wire cannot reach the 6.0 V of the battery. The series resistor and the wire RQ have the same resistance, so 3 V is the maximum possible potential difference across RQ, and **B** must be correct.

PHYSICS

Paper 9702/12
Multiple Choice

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

General comments

Candidates should be reminded to read the whole question before attempting to give an answer. The information in full should be used to complete a calculation or draw a conclusion. It is important that candidates read the question carefully and that they are sure that the answer chosen is correctly related to the question.

Candidates found **Questions 5**, **11**, **19**, **20**, **34** and **35** difficult, and they found **Questions 1**, **4**, **9**, **23**, **31** and **33** to be relatively easy.

Comments on specific questions

Question 2

A significant number of candidates found it difficult to combine the SI base units of the volt with the basic equation for resistance of $R = V/I$. The base unit of A^{-2} should be in the final expression for the SI base units of resistance. Weaker candidates tended to give **A** or **C**, both of which contain A^{-1}, rather than the correct answer **B**.

Question 3

A number of candidates identified vectors and scalars in both **A** and **C**. Weight may have caused the selection of **A** as this is often confused with mass. Power or pressure in **C** may have caused this selection as some candidates incorrectly think that these quantities are vectors.

Question 5

A common incorrect answer was **B**. Candidates choosing **B** may have thought that Z is an accurate measuring instrument. An average of the measurements using Z will be much greater than the true value of *V*. Instrument Z is neither accurate nor precise. The only accurate instrument is X.

Question 6

Some candidates calculated the time to run 100 m using the acceleration of $2.5\,\text{m s}^{-2}$ for the complete distance. The information that the acceleration stops when the runner reaches a speed of $10\,\text{m s}^{-1}$ was not used by these candidates.

Question 7

There were a number of candidates that did not use the link between resultant force and change in momentum per unit time, selecting the incorrect answers **A** or **C**.

Question 10

A significant number of candidates chose incorrect answers **A** or **C**. Kinetic energy needs to be conserved in this elastic collision. This is not possible if both the masses have a speed of $v/2$ after the collision. The kinetic energy would be reduced to half of its original value in this case.

Question 11

Many candidates chose the incorrect answers **A**, **B** and **C**. These candidates may not have seen the information about the particle having an initial horizontal speed, or considered that a force is necessary in the direction of travel for the particle to move to the position shown.

Question 13

A significant number of candidates chose answer **C** rather than the correct **A**. All three arrows showing the direction of the forces should show the head of one vector arrow meeting the tail of the next vector arrow when the system is in equilibrium.

Question 15

A significant number chose **B** which suggests that the information given was not read carefully. At the half-way stage the rope had not started to extend, so the correct answer is **D**.

Question 19

In order for the power to remain constant, the force must be very large when the velocity is low at the start. The graphs **B**, **C** and **D** showing $F = 0$ at $v = 0$ must all be incorrect.

Question 20

If the metal cylinder is able to withstand a compressive force of 4.0 kN without plastic deformation, the force at the elastic limit of the cylinder must be greater than 4.0 kN. Only the pair of values **D** results in an elastic limit greater than 4.0 kN.

Question 21

A large number of candidates gave the incorrect answer **C**. Area Q + R under the graph represents the work done to extend the wire, but some of this work results in permanent deformation so it does not become elastic potential energy. The area that represents the elastic potential energy (the energy that is recovered when the load is removed) is R (answer **D**).

Question 29

Many candidates did not use the information given in the question that the phase difference between the two sources was 180°, and these candidates gave the incorrect answer **C**.

Question 32

Candidates needed to use the relationship $E = V / d$, recognising that d is decreasing while V is constant. Some candidates chose **C**, which incorrectly shows E reaching a constant value.

Question 34

A good approach to answer this question is to use the ideas that the ratio of the potential difference (p.d.) across each resistor equals the ratio of the resistance values, and the total p.d. across the two resistors is 16 V.

Question 35

The resistance of the wire is proportional to L / r^2. This ratio needed to be reduced by a half to reduce the resistance R to ½R.

Question 36

Candidates should be reminded that the total resistance for a combination of resistors connected in parallel is always less than or equal to the smallest value of the total resistance of any branch.

PHYSICS

Paper 9702/13
Multiple Choice

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

General comments

Candidates should be reminded to read the whole question before attempting to give an answer. The information in full should be used to complete a calculation or draw a conclusion. It is important that candidates read the question carefully and that they are sure that the answer chosen is correctly related to the question.

Candidates found **Questions 4**, **15**, **22**, **25**, **26**, **33**, and **37** difficult. They found **Questions 3**, **7**, **10**, **16**, **23**, **30**, **32** and **34** to be relatively easy.

Comments on specific questions

Question 1

The majority of candidates gave the correct answer **C**. There were a significant number giving **B** and **D**. This may be a result of guessing or perhaps by some candidates who did not notice that the question was looking for an incorrect statement.

Question 4

The majority of the candidates gave the correct answer **B**. There were a significant number of candidates who chose **C** and **D**. These answers suggest the candidates did not read that the ammeter gave a full-scale deflection for a current of 2.0 A. The needle on the ammeter scale being below the full-scale deflection eliminates these two answers.

Question 6

A significant minority of candidates chose the incorrect answers **C** and **D**. Both of these graphs show the stone with a non-uniform acceleration in the vertical direction. In **D**, the stone does not start from rest in the vertical direction.

Question 11

The majority of candidates gave the correct answer **A**. A significant number gave **B** where the velocity is shown to increase uniformly; this is not consistent with a resistive force acting that depends on the velocity of the sphere. Answers **C** and **D** could have been easily eliminated because they do not show an initial velocity of zero.

Question 13

There were a number of candidates who used the wrong component for the forces acting in the cable against the force *R*, giving **C**. A significant number only used one component value of the force acting from the two sections of the cable and these candidates obtained incorrect answer **B**.

Question 15

Many candidates gave the correct answer **D**. Weaker candidates often chose **B**. These candidates possibly confused total energy with kinetic energy. It is a basic law of physics that total energy is constant, so **D** is correct and **B** cannot be correct.

Question 19

The majority of candidates gave the correct answer **D**. There were a significant number of candidates giving all three alternative incorrect answers. The errors made were possibly taking a point for the values of *F* and *e* or using the gradient rather than the inverse for the ratio $\Delta F / \Delta e$.

Question 22

Candidates found this question difficult and a minority of candidates gave the correct answer **B**. A significant number thought that the particle moved forward with the wavefront instead of oscillating about a fixed point.

Question 25

Approximately half of the candidates were able to give the correct answer **B** for this 'bookwork' question. The wavelength is 100 nm. Over half of the candidates incorrectly identified this wavelength as either visible or infrared.

Question 26

A common incorrect answer was **C**. The points equidistant from the central node N_2 are out of phase by 180°.

Question 33

Only the strongest candidates gave the correct answer **B**. Many other candidates ignored the power restriction for each individual resistor and calculated the potential difference for a total resistance of 150 Ω.

Question 37

Many candidates gave answer **A**, which assumes the same ratio across each pair of resistors that are facing each other in the two circuits. This is not correct because the two cells have different e.m.f.s. A correct approach is to determine the potential difference across either the 100 Ω or 50 Ω resistor and then find the potential at the midpoint of the left-hand circuit. The same potential at the right-hand midpoint can then be used to determine the resistance of R.

PHYSICS

Paper 9702/21
AS Level Structured Questions

Key messages

- Candidates should be encouraged to learn precisely certain definitions, laws and principles. The omission of a single key word can lead to marks not being awarded if it is an important part of a definition.
- Candidates should ensure that they do not prematurely 'round off' any intermediate answers in a numerical calculation as this can lead to an inaccurate final answer.
- The final answer to a numerical question should be stated to an appropriate number of significant figures. In general, the final answer should be stated with a minimum of two significant figures.
- It is important that candidates practise answering questions that are of the same standard as those in the examination. Working through past papers is a way of achieving this.

General comments

Although some candidates performed very well in the examination, a significant number of candidates found the paper difficult. Some candidates did not attempt to answer many of the questions. The pattern of responses did not suggest that candidates had insufficient time to complete the paper.

Comments on specific questions

Question 1

(a) (i) The most common incorrect definition of displacement was 'the distance between two points'. Another common incorrect definition was 'the product of velocity and time'.

(ii) The definition of acceleration was well known. A common incorrect definition was 'velocity divided by time', which is not sufficiently precise.

(b) (i) The majority of the correct calculations used Pythagoras' theorem to find the vertical component of velocity. An alternative correct calculation could be done by using trigonometric functions.

(ii) Many candidates did not appreciate that they needed to consider the vertical component of the car's motion. Some candidates correctly quoted an appropriate equation of uniformly accelerated motion, but did not realise that the equation should be used with the vertical component of the car's velocity.

(iii) The candidates needed to understand that the horizontal component of the car's velocity remains constant when air resistance is negligible. A common misconception was that the car had an acceleration in the horizontal direction.

(iv) The symbol equation for kinetic energy was generally well known. Many candidates found it challenging to calculate the actual kinetic energy of the car at its maximum height. A significant number of candidates incorrectly assumed that the car would have zero kinetic energy at maximum height.

(c) Although many candidates realised that the velocity-time graph would be a straight line, only a small minority showed that they understood that the vertical component of the car's velocity would change sign and that the final magnitude of the velocity would be greater than the initial magnitude.

Question 2

(a) Most candidates knew the formula for the momentum of a single object. A common error in the calculation of the common final speed of the block and ball was to add, instead of subtract, the magnitudes of the initial momenta of the ball and block.

(b) (i) 1. A common mistake was to subtract, instead of add, the initial speeds.

2. Stronger candidates were able to state that the relative speed of separation of the block and ball was zero after the collision. Weaker candidates often thought that the relative speed of separation was equal to the common speed of the block and ball after the collision.

(ii) The candidates were asked to use the relative speed of approach and the relative speed of separation to explain whether the collision was elastic or inelastic. An explanation that was based only on the change of total kinetic energy did not answer the question that had been asked. Candidates should be encouraged to read the question carefully.

(c) Although some candidates were able to give a general statement of Newton's third law, most candidates found it difficult to apply the law to the collision.

Question 3

(a) (i) The most common incorrect definition of power was 'the product of force and velocity'.

(ii) Although the strongest candidates could state what is meant by gravitational potential energy, the majority gave answers that were too vague such as 'the energy due to gravity'.

(b) (i) The calculation of the power produced by the thrust force was reasonably well done. A common error was to multiply the thrust force by the rate of increase in height of the aircraft ($3.3\,\mathrm{m\,s^{-1}}$) instead of the velocity of the aircraft ($45\,\mathrm{m\,s^{-1}}$).

(ii) 1. A significant number of candidates were not able to apply the relationship between work done, power and time to the context of the question.

2. The general symbol equation for the change in gravitational potential energy of an object was well known. Some candidates did not know how to calculate the increase in the height of the aircraft.

3. Many candidates did not appear to understand the energy transfers that were taking place as the plane moved along its path and so they were unable to calculate the work done against the air resistance.

(iii) Many candidates did not attempt this part of the question. The strongest candidates knew how to calculate the force due to the air resistance from the work done against the air resistance.

(iv) In addition to correctly stating that the aircraft was in equilibrium, it was necessary to give a supporting explanation. A common misconception was that the aircraft could not be in equilibrium because it was moving. Another misconception was that the aircraft could not be in equilibrium because the aircraft's engine is exerting a thrust force on the aircraft.

Question 4

(a) Most candidates correctly referred to two or more waves meeting at a point. A small proportion went on to clearly state that the resultant displacement at that point is equal to the sum of the displacements of the individual waves at that point. Some candidates incorrectly referred to amplitude instead of displacement.

(b) (i) A small minority of the answers stated the correct meaning of *coherent*. A common error was to state that it meant only that the waves had the same frequency. Many candidates thought that it meant that the waves must be in phase.

(ii) 1. Only the strongest candidates were able to deduce the phase difference of the waves meeting at a particular bright fringe.

2. Most candidates were unable to state the path difference of the waves meeting at a particular dark fringe. Many appeared to guess the path difference or did not attempt to answer the question.

(iii) The symbol equation for double-slit interference of light was usually stated correctly. Weaker candidates were often unable to calculate the correct value of the fringe separation from the distance across five bright fringes.

(iv) It was generally understood that the separation of the fringes would be reduced. However, candidates found it difficult to give a correct explanation for this change.

(v) The majority of the candidates did not fully understand how increasing the light intensity would affect the appearance of the fringes. The stronger candidates were able to state that the bright fringes would become brighter and that the fringe separation would stay the same. A common misconception was that the dark fringes would become either darker or brighter.

Question 5

(a) The strongest candidates were able to state what was meant by an electric field. Weaker candidates sometimes attempted to describe a magnetic field.

(b) Although the derivation of the equation proved to be straightforward for stronger candidates, a significant number of other candidates made no attempt to answer the question. The use of base units to show that the equation was homogeneous was not sufficient to gain credit.

(c) (i) Most candidates seemed to realise that nucleon number and proton number would be conserved during the decay process. Some candidates did not appear to know the composition of an α-particle. Others confused the number of neutrons with the number of nucleons.

(ii) Stronger candidates were able to explain that the difference in mass was linked to the release of energy to ensure the conservation of mass-energy. Many of the weaker candidates incorrectly thought that the difference in mass was due to the release of other particles such as electrons.

(iii) Many candidates made mistakes when manipulating the algebra. Others were unable to complete the calculation because they could not deduce the mass and/or the charge of the α-particle and the plutonium nucleus.

Question 6

(a) Many candidates only stated that the sum of the e.m.f.s is equal to the sum of the p.d.s. A full statement of Kirchhoff's second law should also make reference to a loop in a circuit.

(b) (i) There were different ways of calculating the final answer. The most common and successful way was to first calculate the combined resistance of the two wires connected in parallel. Many candidates were able to do this, but often did not realise that the resistance of the variable resistor could then be calculated by treating the circuit as a potential divider.

(ii) Although this part of the question was straightforward for many candidates, there were a significant number who were unable to state a symbol formula for electrical power.

(iii) 1. The equation relating resistance to resistivity, length and cross-sectional area was well known. Many candidates made mistakes with their algebraic manipulation when calculating the ratio of the two lengths. Weaker candidates often thought that the ratio of the two lengths was equal to the ratio of the two cross-sectional areas.

2. Many candidates did not appear to know that the appropriate formula was listed on the Formulae page of the examination paper. Candidates should be reminded to check this page if they are unable to recall an equation, as it may be given to them there. Weaker candidates simply stated the ratio of the two cross-sectional areas as their final answer or did not attempt the question.

PHYSICS

Paper 9702/22
AS Level Structured Questions

Key messages

- Candidates should be encouraged to learn precisely certain definitions, laws and principles. The omission of a single key word can lead to marks not being awarded if it is an important part of a definition.
- Candidates should ensure that they do not prematurely 'round off' any intermediate answers in a numerical calculation as this can lead to an inaccurate final answer.
- The final answer to a numerical question should be stated to an appropriate number of significant figures. In general, the final answer should be stated with a minimum of two significant figures.
- It is important that candidates practise answering questions that are of the same standard as those in the examination. Working through past papers is a way of achieving this.

General comments

In general, candidates could improve by further study of stationary sound waves, average drift speed of free electrons and β^- decay. They found **Questions 2(b)(iii)**, **4(b)(i)**, **6(a)**, **7(b)** and **8(b)(iii)** to be challenging.

The candidates did not have any difficulty understanding the language used in questions. There was no evidence of candidates having insufficient time to complete the paper.

Comments on specific questions

Question 1

(a) The vast majority of the candidates found it straightforward to calculate the horizontal component of the velocity. Most candidates used Pythagoras' theorem. An alternative correct calculation could be done using trigonometric functions. Candidates should always remember to state the subject of any equation that they write.

(b) (i) Most candidates were able to draw a downward sloping line from the correct starting point. However, many did not draw the line carefully enough, and this often resulted in an inaccurate end point of the line. Straight line graphs should always be drawn using a ruler and not freehand. Some candidates ended their graph line at the instant the ball reached its maximum height instead of at the time the ball returned to the ground. A very small number of candidates drew a speed–time graph instead of a velocity–time graph.

(ii) Most candidates were able to draw a horizontal line from the correct starting point, but in many cases the graph line did not end at the correct point. A very small number of candidates did not follow the instruction to label both of their graph lines.

(c) The majority of the candidates were able to calculate the maximum height by using an appropriate equation for uniformly accelerated motion. A common error was to substitute the value of the acceleration of free fall with the wrong sign. Another common error was to substitute the actual velocity ($6.0\,\text{m}\,\text{s}^{-1}$) or the horizontal component of the velocity ($3.6\,\text{m}\,\text{s}^{-1}$), instead of the vertical component of the velocity ($4.8\,\text{m}\,\text{s}^{-1}$), into the symbol equation.

(d) Almost all of the candidates could state the symbol formulae for the kinetic energy and the change in gravitational potential energy. Only the stronger candidates realised that the velocity of the ball at its maximum height is equal to the initial horizontal component of the velocity of the ball. A small number of candidates presented the required ratio in fractional form instead of working out its final value. Sometimes the final answer was inappropriately expressed to only one significant figure.

(e) The candidates needed to explain that the force due to air resistance acts in the opposite direction to the ball's velocity. Therefore, the presence of air resistance leads to a larger resultant force acting on the ball in the downwards direction. A common misconception among the weaker candidates was that an intrinsic upwards force acts on the ball so that the presence of air resistance leads to a reduction in the magnitude of an upwards resultant force. Some of the weakest candidates seemed to consider the motion of a falling ball and made references to it reaching terminal velocity.

Question 2

(a) The vast majority of the answers were correct. A small number of candidates stated base quantities instead of base units.

(b) (i) Most candidates realised that force X was a frictional force. Common incorrect answers included 'contact force', 'reaction force' and 'the horizontal component of the weight'.

(ii) The majority of the candidates were able to calculate the moment of the force of 90 N. The application of the principle of moments was generally problematic as many candidates were unable to deduce a correct expression for the moment of the weight of the beam.

(iii) The strongest candidates realised that the resultant force on the beam is zero, and that therefore the magnitude of force X is equal to the magnitude of the horizontal component of the force of 90 N. Some candidates gave inappropriate and overcomplicated calculations based on the moments of the forces.

Question 3

(a) It was important for the candidates to refer to *total* momentum when stating the principle of conservation of momentum. The terms 'moment' and 'momentum' were sometimes confused with each other. A small number of the weaker candidates incorrectly stated that total momentum was only conserved in elastic collisions. Some of the weakest candidates inappropriately stated either the principle of moments or the principle of conservation of energy.

(b) (i) In 'show that' questions, credit is given for showing the calculation as well as the final answer. Candidates must carefully present each step of the calculation. It is also important to explicitly state the subject of any equation. When an equation is rearranged, the new subject should also be given. A common error was to confuse the formula for the volume of a cylinder with the formula for the volume of a sphere.

(ii) This question was generally well answered. A small minority of candidates multiplied the change in momentum by the time taken instead of dividing the change in momentum by the time taken. The weakest candidates sometimes attempted to calculate a force that corresponded to the weight of air.

(iii) Many candidates gave a general statement of Newton's third law, but did not explain how the law applied to the movement of the air by the propeller. It was important to clearly state what the two equal and opposite forces act on. Successful explanations were both precise and explicit.

(iv) The majority of the candidates could calculate the resultant force acting on the car. Only the stronger candidates then went on to determine the frictional force by subtracting the resultant force from the thrust force on the car. A common error was to add, instead of subtract, these two forces.

Question 4

(a) Many statements were incorrect. This was often because the candidates ignored the instruction to refer to the direction of propagation of energy in their answer.

(b) (i) Only a small minority of the candidates were able to deduce from the graph that the two air particles were at adjacent antinodes so that the phase difference between their vibrations was 180°. The most common incorrect answers were 0 and 360°.

(ii) Most calculations were only partially correct. Many candidates misinterpreted the graph and used an incorrect wavelength of 25 cm instead of the correct wavelength of 50 cm. A small number of candidates made a power-of-ten error by not converting the unit of the wavelength from cm to m.

(iii) The required values of the square of the amplitude were usually read correctly from the graph. A common mistake when calculating the ratio of the amplitudes was to simply forget to take the square root of the values from the graph. A small proportion of the candidates incorrectly expressed their final answer to one significant figure. Candidates needed to express their answer as a single numerical value and not just leave it in the form of a fraction.

Question 5

(a) This question was generally well answered. Sometimes a power-of-ten error was made when converting the unit of the wavelength from nm to m.

(b) Sometimes candidates calculated a wavelength that gave a diffraction maximum at the required angle of 49°, but which did not correspond to *visible* light. Many of the weaker candidates either simply reversed the calculation in **(a)** or made no attempt to answer the question.

Question 6

(a) A small proportion of the candidates were able to recall the definition of the volt. A common incorrect definition was 'ampere ohm'. There were many candidates who did not make the distinction between the definition of a quantity and the definition of a unit. Consequently there were many attempts to define electric potential difference instead of the volt.

(b) (i) Most candidates were able to calculate the current in the circuit.

(ii) In the vast majority of cases, a correct calculation was performed by applying Ohm's law to resistor Z.

(iii) A correct symbol formula for electric power was almost always included in the calculation. Many candidates did not read the question carefully and calculated the efficiency with which the battery supplies power to resistor Z or resistor X instead of to lamp Y.

(iv) The relevant symbol equation relating resistance and resistivity was usually recalled correctly. Sometimes errors were made in manipulating the algebra and often this led to an answer that was the reciprocal of the correct answer.

Question 7

(a) The vast majority of the candidates correctly identified *A* as the cross-sectional area of the wire. Only a small minority knew that *n* represented the 'number of free electrons per unit volume' or the 'number density of free electrons'. A common mistake was to refer to just 'electrons' instead of *free* electrons; most candidates would benefit from being reminded that not all of the electrons in a wire contribute to the electric current. Another common error was to refer to just 'density' instead of number density. Referring to just density was too vague as it could imply mass density rather than number density.

(b) Stronger candidates could deduce that the drift speed of the electrons would increase by a factor of four, although many candidates drew a straight line and did not realise that the correct line is a curve with an increasing gradient.

Question 8

(a) Although many candidates found this part of the question to be straightforward, a significant number incorrectly stated that a quark is a lepton.

(b) (i) Most candidates understood how the nucleus changes during β^- decay. A common misconception among very weak candidates is that β^- decay causes the nucleon number of a nucleus to decrease by one.

(ii) Only the stronger candidates knew that it is the weak interaction (between quarks) that gives rise to β-decay. Many candidates incorrectly stated either 'fission' or 'β-decay' as their answer.

(iii) The most common correct reason given for the difference in energy was that an antineutrino is emitted. Very few candidates stated that the nucleus X also has kinetic energy. Weaker candidates often commented on the loss of thermal energy.

PHYSICS

Paper 9702/23
AS Level Structured Questions

Key messages

- Candidates should be encouraged to learn precisely certain definitions, laws and principles. The omission of a single key word can lead to marks not being awarded if it is an important part of a definition.
- Candidates should ensure that they do not prematurely 'round off' any intermediate answers in a numerical calculation as this can lead to an inaccurate final answer.
- The final answer to a numerical question should be stated to an appropriate number of significant figures. In general, the final answer should be stated with a minimum of two significant figures.
- It is important that candidates practise answering questions that are of the same standard as those in the examination. Working through past papers is a way of achieving this.

General comments

Candidates need to take care to distinguish between quantities and units. In **Questions 1(a)** and **6(a)**, some candidates interchanged units and quantities without making it clear that they understood the difference.

Sketching graphs based on the information supplied in the question is an important skill. In **Questions 2(b)(iv)** and **6(c)**, candidates needed to sketch graphs representing unfamiliar situations, but were expected to apply their knowledge and understanding to work out the correct shape of each graph.

In general, there was no evidence that the candidates were short of time to finish their answers.

Comments on specific questions

Question 1

(a) The majority of candidates made a good start and gave at least one SI base quantity. There were some candidates who stated base units instead of the required base quantities.

(b) (i) The majority of candidates were able to resolve the two tension forces in the wire and calculate the weight of the tyre. A significant number resolved only one of the tension forces and equated this value to the weight of the tyre. A very small minority incorrectly equated the weight to the resolved horizontal component of the tension.

(ii) 1. The correct symbol formula for stress was used by a large majority of the candidates. A significant number used the weight of the tyre for the force instead of the tension in the wire. A small minority made a power-of-ten error when converting the unit of cross-sectional area from mm^2 to m^2.

2. The majority of the candidates gained full credit by substituting their value of the stress from the previous question part into the equation for the Young modulus. A small minority made a power-of-ten error or incorrectly rearranged the equation.

Question 2

(a) A significant number of candidates were unable to describe kinetic energy with the precision required.

(b) (i) This question was well answered by the majority of candidates. In this 'show that' question, candidates needed to give the symbol equation for kinetic energy and also show the full substitution of values before stating the final answer.

(ii) 1. This question was very well answered. Most of the candidates used the correct expression for the change in gravitational potential energy and were awarded full credit. A very small number inappropriately used $10\,m\,s^{-2}$ instead of $9.81\,m\,s^{-2}$ for the acceleration of free fall.

2. The correct answer was calculated by the majority of the candidates. A small number gave the gain in gravitational potential energy as the work done against air resistance. This suggests that they did not read the question carefully or they did not understand the significance of the potential energy gained being unequal to the kinetic energy lost.

(iii) The majority of the candidates obtained the correct answer using work done equal to the product of air resistance and the vertical distance travelled by the shell. Those that calculated the average deceleration often omitted the weight of the shell when giving the answer for the air resistance and so merely calculated the resultant force. A small minority calculated the weight of the shell and stated that this was the equal to the air resistance.

(iv) Only a small minority of the candidates showed the correct variation of the velocity with time. A significant number started the graph with a velocity of zero at $t = 0$ and showed an increase in velocity as the shell climbed to its maximum height. Some drew a straight line with a negative gradient suggesting that the deceleration was constant.

(v) The majority of the candidates were able to state that the air resistance acts in opposite directions when the shell rises compared to when it falls. The majority did not compare the change in the magnitude of the force in these two situations. Many incorrectly suggested that the magnitudes of the forces were equal. A small number of candidates stated correctly that the magnitude of the force decreased as the shell rose and increased as it fell.

Question 3

(a) The majority of the candidates gave a correct response. There were a significant number of candidates who gave the relationship between force and acceleration. This is a special case of the second law, but is not a complete statement and as such is too imprecise to be given credit.

(b) (i) There were many answers that correctly showed the full substitution of values and a well-structured presentation of the determination of the mass of water. There were also many answers that showed no subject for a variety of expressions that led to the value of the mass. These solutions were difficult to follow and often led to mistakes being made by the candidate, so candidates should be encouraged to show the subject of any equation clearly.

(ii) A large majority were able to correctly calculate the change in momentum of the water. A small number gave the answer to only one significant figure.

The majority of the candidates used Newton's second law and equated the rate of change in momentum of the water to the force on the water. There were many solutions that ignored the change in momentum calculated in the previous part, and equated the force on the water to the weight of water.

(iii) The majority of the candidates gave a general statement of Newton's third law but found it difficult to apply it to the situation in the question. The action and reaction forces described by candidates needed to be related to the forces acting on the two different bodies in the question, i.e. the force on the water and the equal and opposite force on the rocket. Many candidates referred to the force between the compressed air and the water but did not go on to relate this to the force on the rocket. A significant number of candidates incorrectly thought the relevant forces were between the ground and the water.

(iv) The majority of candidates found the calculation of the mass to be straightforward and gained full credit.

The calculation of the acceleration of the rocket produced by the majority of candidates did not account for the weight of the rocket. Candidates need to remember that in the equation $F = ma$ the F relates to the resultant force on the mass m.

Question 4

(a) The majority of the candidates gave the correct length on the graphs for the wavelength and for the period but did not label the horizontal axes as distance and time respectively. The amplitude was also often marked correctly but without labelling the vertical axis as displacement. Weaker candidates often wrongly labelled the horizontal axis as wavelength or period and wrongly labelled the vertical axis as amplitude.

(b) (i) There were good answers from a number of candidates. Full credit could not be obtained by candidates who only gave a general description of how stationary waves are formed and did not describe the formation of stationary waves on the string. Many answers were incomplete because they did not describe the point where the wave was reflected on the string or did not explain that the waves then had to travel in opposite directions and superpose.

(ii) The majority of candidates were able to determine that a time of 100 ms was equivalent to two and a half oscillations. A significant number went on to determine that the displacement was zero after these oscillations.

Many candidates did not realise that in one oscillation the particle travels a distance that is equivalent to four times the amplitude.

(iii) 1. The majority of the candidates calculated the frequency correctly. Some candidates did not convert the unit of ms into s.

2. The majority of the candidates were able to calculate the wavelength of the wave, and many went on to calculate the horizontal distance from X to Y correctly.

Question 5

(a) The derivation of the symbol equation was found to be straightforward by the majority of the candidates.

(b) The calculation of the mass in kg was completed by the majority of candidates. The link to the mass in atomic mass units caused a problem for a small number of candidates. A few confused the mass of a proton and the atomic mass unit.

(c) There were many candidates who gave the correct number of protons and neutrons. There were a significant number of answers where the candidate did not use correctly the information given for the charge and mass of the particle.

(d) (i) Many candidates recognised that the second nucleus, being an isotope, would have the same number of protons but a different number of neutrons. The majority of these candidates stated that the force depended on the electric field and the charge. Some candidates used the equation force = mass × acceleration inappropriately and incorrectly deduced that the mass would affect the force.

(ii) A significant number of candidates correctly realised that there would be a difference in the acceleration due to a difference in the mass because the force remained the same.

Question 6

(a) Many answers referred to the quantities current and time but did not refer to the units that are required to define the coulomb.

(b) Only the stronger candidates were able to give both of the possible charges. The idea that the charge had to be an integer value times the elementary charge seemed to be missed by a large number of candidates.

(c) The majority of the graphs correctly showed the speed starting at v_s as given in the question. There was a minority that showed the correct variation of the speed down to $0.25v_s$ at end T. There were many incorrect graphs starting at the origin and showing an increase in speed with the increase in cross-sectional area. A significant number of candidates incorrectly showed a linear decrease in the drift speed or incorrectly showed the drift speed halving when the diameter doubled.

Question 7

(a) Most candidates correctly stated that the total current entering a junction is equal to the total current leaving the junction. Some answers did not refer to the total current or to a junction.

(b) (i) Many candidates found it difficult to interpret the circuit connections for R and so did not give the correct answer of zero potential difference.

Candidates generally realised correctly that the resistor R was being connected across the battery when the slider was moved to Y.

(ii) Candidates found this question difficult. A significant number gave half the e.m.f. of the battery as their answer. Successful candidates recognised that this was effectively a circuit with two 400 Ω resistors in parallel followed by one 400 Ω resistor in series. Many weaker candidates simply divided 9.6 V by 3, suggesting a series circuit for three 400 Ω resistors.

PHYSICS

Paper 9702/31
Advanced Practical Skills 1

Key messages

- Candidates are encouraged to record all their raw data (in the table and elsewhere) to the precision of the instrument used, remembering to include units where appropriate.

- Candidates need to practise plotting and reading off graphs accurately. Graph scales should be chosen so that the plotted points occupy at least half of the graph grid along each axis, but this should not be achieved by selecting an awkward scale that is difficult to use. It is worth double-checking the plotting, especially when a point appears to be anomalous.

- Many candidates find it difficult to draw lines of best fit. To practise and develop this skill, candidates might find it helpful to draw a straight line on a transparent plastic sheet and use it as an overlay, sliding or rotating it to find the line of best fit. A transparent 30 cm ruler and sharp pencil are essential when 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. General points such as 'avoid parallax error' or 'use more precise measuring instruments' will not usually gain credit without further detail. Candidates should be encouraged to write about four different problems and consequently four different solutions to address these problems, and should not try to state four solutions to the same problem.

General comments

There was no evidence that centres had 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.

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 almost all the candidates. They demonstrated good skills in the generation and handling of data but can improve by giving more thought to the analysis and evaluation of experiments.

Comments on specific questions

Question 1

(a) Many candidates stated values of *x* that were in the appropriate range and had consistent units. Some candidates omitted the unit.

(b) Most candidates stated a value of *T* in the appropriate range and with a unit. Some candidates stated a value that was too small (e.g. by measuring the time for half an oscillation) or too large (e.g. measuring the time for 10 oscillations and then forgetting to divide by 10).

(c) Many candidates were able to collect six sets of values of *x* and *T* without assistance from the Supervisor.

Some candidates chose a small range over which to conduct the experiment, so the values ended up too close together. It was expected that candidates consider the entire range of the holes provided. Many chose to decrease *x* step by step (going from one hole to the next consecutive hole) from the initial setup of the largest measurement of *x* but then stopped before reaching the last two holes, so did not make use of the full range available.

Many candidates were awarded credit for the column headings, giving both the quantity and correct unit for each heading, separated by a solidus or with the unit in brackets. Some candidates omitted either the unit or the separating mark for one of the columns, in particular the T^2 / x column.

Many candidates correctly recorded their raw values for *x* to the nearest 0.1 cm. Some candidates stated their measurements to the nearest cm (e.g. 45 cm) without considering that they can make the measurement to the nearest mm using the ruler provided. A few candidates stated measurements with all trailing zeros in the mm place giving the false impression of precision to 0.1 mm, e.g. 10.50 cm.

Many candidates correctly recorded their calculated values in x^2 to two or three significant figures. Some candidates either stated too many or too few significant figures, or aimed to be consistent in their use of decimal places at the expense of significant figures. This often increased the amount of scatter in the results plotted on the grid.

Most candidates calculated values for T^2 / x correctly. Some candidates incorrectly rounded their answers and this did not gain credit.

Overall the table work was done well by candidates.

(d) (i) A few candidates plotted the wrong graph or omitted labels. Compressed scales that did not use enough of the grid (in either the *x* or *y* direction) were often seen and could not be awarded credit. There were many instances of awkward scales (e.g. based on 3, 6, 11 etc. or having 15 squares between scale markings). A minority of 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. This type of scale cannot be awarded credit and it was very common for candidates using such awkward scales to lose further credit later for read-offs that were incorrect.

Some candidates used irregular (i.e. non-linear) scales. Irregular scales could not be given credit, and often the data could not be awarded credit for quality either, because the error was often in the region of the plotted points. Candidates should be encouraged to set up their graphs to make them easy to work with in later parts of the question.

Some points were drawn as dots with a diameter greater than half a small square. Many points were incorrectly plotted so that they were greater than half a square from the correct position. 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 with no more than one point being circled.

There is no credit specifically for identifying anomalous points, so candidates should be reminded that they do not need to identify an anomalous point if they do not think they have one. If time permits and candidates identify an anomalous point from the graph trend, they should repeat this reading and check their calculation.

(ii) Some candidates were able to draw carefully considered lines of best fit, but others joined the first and last points on the graph or any three points on the 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 (candidates used too small a ruler), a double line (broken pencil tip) 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.

(e) Most candidates recognised that *A* was equal to the gradient and *B* was equal to the intercept. Some candidates recorded a value with consistent units for *A* and *B*. Other candidates stated incorrect units or often omitted the units.

Question 2

(a) (i) Most candidates recorded the value of *M* with a unit and at least to the nearest 0.1 g. Some candidates omitted units, whilst others stated the mass measurement to the nearest 1 g.

(ii) Most candidates correctly calculated the mass of one paper clip.

(iii) Many candidates correctly justified the number of significant figures they had given for the value of *m* with reference to the number of significant figures used in *M*. Some candidates gave reference to just 'raw readings' or 'the values in the calculation' without stating what these values were.

(b) (i) Most candidates measured the value of *S* with a unit and in the appropriate range. Some candidates omitted units, whilst others stated a value of *S* that was out of range.

(ii) Nearly all candidates correctly calculated *c*.

(c) (i) Many candidates stated the values of *p* and *q* so that the total was 25 and repeated the experiment to get multiple values. Some candidates did not show evidence that they had repeated the experiment. A few candidates obtained results for *p* and *q* that did not add up to 25.

(ii) Most candidates were familiar with the equation for calculating percentage uncertainty. Some candidates made too small an estimate of the absolute uncertainty in the value of *p*, typically 0.1, when whole paper clips were measured. Some candidates repeated their readings and correctly gave the uncertainty in *p* as half the range, although other candidates did not halve the range.

(d) Most candidates recorded second values of *p* and *q*. Most candidates correctly recorded a second *q* value that was smaller than their first *q* value when both spheres were placed on the chain.

(e) (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 $1/k$, or inadvertently substituted the wrong values.

(ii) Some 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%, 15% or 20%. Some candidates referred to the percentage uncertainty calculated for *p* and, although not ideal, this was also credited. Some candidates omitted a criterion, or gave general statements such as 'this is valid because the values are close to each other', which could not be accepted. Occasionally candidates gave a contradictory statement such as 'yes, my results do not support this relationship as my % difference is less than 10%' or an incorrect statement such as 'my results support this relationship as my % difference is greater than 10%'.

(f) 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. Many problems stated by the candidates correctly linked to the practical problems encountered at each stage of the experiment and were presented chronologically. Occasionally, candidates related their limitations and solutions to the experiment in **Question 1** and these could not be given credit.

Various reasons for the difficulty in measuring the number of paper clips linked to the large increment in mass were accepted. The solution to use smaller or lighter paper clips was accepted and commonly seen. Reasons relating to the difficulty in keeping the spheres on the chain without falling off or the paper clips themselves flipping over or catching on the board as the chain moves were also commonly written about and given credit.

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', etc. Unrealistic solutions were also not given credit, e.g. 'robotic arm' or 'mechanical hand'. Problems that were irrelevant or that could have been removed if the candidate had taken greater care were not given credit. Vague or generic answers such as 'too few readings' (without stating a consequence), 'faulty apparatus', 'use of a fiducial marker' (as this was not relevant in this experiment) or 'use an assistant' were also 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 9702/33
Advanced Practical Skills 1

Key messages

- Candidates are encouraged to record all their raw data (in the table and elsewhere) to the precision of the instrument used, remembering to include units where appropriate.

- Candidates need to practise plotting and reading off graphs accurately. Graph scales should be chosen so that the plotted points occupy at least half of the graph grid along each axis, but this should not be achieved by selecting an awkward scale that is difficult to use. It is worth double-checking the plotting, especially when a point appears to be anomalous.

- Many candidates find it difficult to draw lines of best fit. To practise and develop this skill, candidates might find it helpful to draw a straight line on a transparent plastic sheet and use it as an overlay, sliding or rotating it to find the line of best fit. A transparent 30 cm ruler and sharp pencil are essential when 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. General points such as 'avoid parallax error' or 'use more precise measuring instruments' will not usually gain credit without further detail. Candidates should be encouraged to write about four different problems and consequently four different solutions to address these problems, and should not try to state four solutions to the same problem.

General comments

There was no evidence that centres had 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.

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 almost all the candidates. They demonstrated good skills in the generation and handling of data but can improve by giving more thought to the analysis and evaluation of experiments.

Comments on specific questions

Question 1

(a) Many candidates stated values of I with consistent units. Some candidates did not recognise the current was in mA (e.g. stating 78 A instead of 78 mA or 0.078 A).

(b) Many candidates recorded y with a consistent unit and within range. A minority of candidates stated values of y greater than 75.0 cm, out of range, or omitted the unit.

(c) Many candidates were able to collect six sets of values of *P*, *Q* and *y* without assistance from the Supervisor. Some candidates needed help setting up the circuit.

Many candidates chose a small range over which to conduct the experiment, so the values ended up too close together. It was expected that candidates consider the whole number of resistors provided and use at least the two smallest resistors together and the two largest at the other end of the range. A small minority chose to keep one resistor the same and varied the other.

Many candidates were awarded credit for the column headings, giving both the quantity and correct unit for each heading with both separated by a solidus or with the unit in brackets. Some candidates omitted either the unit or the separating mark for one of the columns, in particular the column for $PQ/(P + Q)$. A few candidates used confused notation, giving the units as $\Omega^2/2\Omega$ instead of Ω.

Many candidates correctly recorded their raw values for *y* to the nearest 0.1 cm. Some candidates stated their measurement to the nearest cm (e.g. 45 cm) without considering that they can make the measurement to the nearest mm using the ruler provided. A few candidates stated measurements with all trailing zeros, giving a false impression of greater precision.

Many candidates correctly recorded their calculated values for $PQ/(P + Q)$ to two or three significant figures. Some candidates either stated too many or too few significant figures, or aimed to be consistent in their use of decimal places at the expense of significant figures. This often increased the amount of scatter in the results plotted on the grid.

Most candidates calculated values for $PQ/(P + Q)$ correctly. Some candidates incorrectly rounded their answers and this did not gain credit.

Overall the table work was done well by candidates. Even those who sought the help of the Supervisor in setting up the circuit usually gained credit for the table. Some candidates did not state their values of *P* and *Q* as resistor values and instead stated current values when the current should have been the same each time.

(d) (i) A few candidates plotted the wrong graph or omitted labels. Compressed scales that did not use enough of the grid (in either the *x* or *y* direction) were often seen and could not be awarded credit. There were many instances of awkward scales (e.g. based on 3, 6, 11 etc. or having 15 squares between scale markings). A minority of 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. This type of scale cannot be awarded credit and it was very common for candidates using such awkward scales to lose further credit later for read-offs that were incorrect.

Some candidates used irregular (i.e. non-linear) scales. Irregular scales could not be given credit, and often the data could not be awarded credit for quality either, because the error was often in the region of the plotted points. Candidates should be encouraged to set up their graphs to make them easy to work with in later parts of the question.

Some points were drawn as dots with a diameter greater than half a small square. Many points were incorrectly plotted so that they were greater than half a square from the correct position. 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 with no more than one point being circled.

There is no credit specifically for identifying anomalous points, so candidates should be reminded that they do not need to identify an anomalous point if they do not think they have one. If time permits and candidates identify an anomalous point from the graph trend, they should repeat this reading and check their calculation.

(ii) Some candidates were able to draw carefully considered lines of best fit, but others joined the first and last points on the graph or any three points on the 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 (candidates used too small a ruler), a double line (broken pencil tip) 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.

(e) Most candidates recognised that *M* was equal to the negative of the gradient and *N* was equal to the intercept from **(d)(iii)**. Some candidates recorded a value with consistent units for *M* ($\text{m}\,\Omega^{-1}$) and *N* (m). Some candidates stated incorrect units, omitted the units or did not recognise that *M* was in fact a positive value i.e. the negative of the gradient.

(f) Some candidates correctly calculated *E* recognising the units as V and substituted their value of *I* in mA. A large number of candidates gave incorrect units, omitted units or, having recognised *I* was measured in mA in **(a)**, did not carry the multiplier forward into this calculation for *E*.

Question 2

(a) Most candidates measured values of *S* in the appropriate range, with a unit and to the nearest mm. Some candidates omitted units, others stated the length measurement to the nearest cm and a few stated a value that was not in range.

(b) (i) Some candidates stated the angle to a tenth of a degree when the precision of the protractor did not justify this, and some gave an incorrect unit (e.g. °C). Some candidates either did not read the instruction correctly or misread the protractor, giving an angle greater than 45°.

(ii) Most candidates are familiar with the equation for calculating percentage uncertainty. Some candidates made too small an estimate of the absolute uncertainty in the value of *A*, typically 1° or 0.5°, given that it was awkward to hold the protractor in the right place. Some candidates repeated their readings and correctly gave the uncertainty in *A* as half the range, although other candidates did not halve the range.

(iii) Many candidates correctly calculated $e_1 \cos \theta$ and $e_2 \sin \theta$. Some candidates incorrectly rounded this value. A minority of weaker candidates incorrectly used their calculator in radian mode.

(iv) Many candidates correctly justified the number of significant figures they had given for the value of $e_1 \cos \theta$ with reference to the number of significant figures used in $(S_1 - S)$ and θ. Many candidates gave reference to just 'raw readings' or 'values in calculation' without stating what these values were, related their significant figures to $\cos \theta$ and not the raw angle θ, or incorrectly related to a different reading e.g. S_2.

(c) Most candidates recorded second values of S_1, S_2 and θ. Most candidates recorded second S_1 and S_2 values that were greater in value than their first set of values at the smaller mass, gaining credit for quality.

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

(ii) Some candidates calculated the percentage difference between their two values of β, and then tested it against a specified numerical percentage uncertainty as a criterion, commonly using 10%, 15% or 20%. Some candidates referred to the percentage uncertainty calculated for θ and, although not ideal, this was also credited. Some candidates omitted a criterion, or gave general statements such as 'this is valid because the values are close to each other', which could not be accepted. Occasionally candidates gave a contradictory statement such as 'yes, my results do not support this relationship as my % difference is less than 10%' or an incorrect statement such as 'my results support this relationship as my % difference is greater than 10%'.

(e) Some candidates were able to calculate a value for *k* with consistent units. Many candidates stated incorrect units or combined their units of β in $\mathrm{cm\,kg^{-1}}$ and *g* in $\mathrm{m\,s^{-2}}$ without a multiplier to provide a consistent unit for *k*.

(f) 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. Many problems stated by candidates correctly related to the measurements taken with a valid reason.

Various reasons for difficulty in measuring the angle were given, such as having to hold the protractor in mid-air or with a shaking hand, or there was parallax error, or there was no vertical reference. Also commonly seen were reasons relating to the difficulty in measuring the length of the extended spring length, e.g. spring constantly moving or the mass moving. To gain credit, the quantity that was difficult to measure must be specified along with the difficulty. Just 'parallax error' on its own cannot gain credit without linking to the angle, and 'difficult to measure the angle' requires the further detail that it is difficult because it was difficult to identify the vertical.

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', 'ensure reading is taken perpendicularly' etc. Unrealistic solutions were also not given credit, e.g. 'robotic arm' or 'mechanical hand'. Problems that were irrelevant or that could have been removed if the candidate had taken greater care were not given credit. Vague or generic answers such as 'too few readings' (without stating a consequence), 'faulty apparatus', 'unstable stands', 'use of a fiducial marker' (as this was not relevant in this experiment), 'digital protractor' or 'use an assistant' were also 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.

The limitations and improvements given by some candidates occasionally related to the experiment in **Question 1** and these could not be given credit.

PHYSICS

Paper 9702/34
Advanced Practical Skills 2

Key messages

- Candidates are encouraged to record all their raw data (in the table and elsewhere) to the precision of the instrument used, remembering to include units where appropriate.

- Candidates need to practise plotting and reading off graphs accurately. Graph scales should be chosen so that the plotted points occupy at least half of the graph grid along each axis, but this should not be achieved by selecting an awkward scale that is difficult to use. It is worth double-checking the plotting, especially when a point appears to be anomalous.

- Many candidates find it difficult to draw lines of best fit. To practise and develop this skill, candidates might find it helpful to draw a straight line on a transparent plastic sheet and use it as an overlay, sliding or rotating it to find the line of best fit. A transparent 30 cm ruler and sharp pencil are essential when 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. General points such as 'avoid parallax error' or 'use more precise measuring instruments' will not usually gain credit without further detail. Candidates should be encouraged to write about four different problems and consequently four different solutions to address these problems, and should not try to state four solutions to the same problem.

General comments

There was no evidence that centres had any difficulties in providing the equipment required for use by the candidates. In some cases, the instruction for the Supervisor to set up the circuit in **Question 1** was not followed. It is essential that any specific instructions such as this are followed. 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.

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 almost all the candidates. They demonstrated good skills in the generation and handling of data but can improve by giving more thought to the analysis and evaluation of experiments.

Comments on specific questions

Question 1

(a) Most candidates recorded a value for *V* in the expected range. Some candidates did not include a unit.

(b) Most candidates recorded a value for *t* in the expected range. A few candidates omitted a unit or misread the stop-watch. Some candidates did not repeat their measurements in order to find a mean value for *t*.

(c) Almost all candidates were able to record six sets of values of *n* and *t* successfully, showing the correct trend. The stronger candidates made the best use of the possible range of values of *n*. Candidates could make maximum use of the apparatus by using a minimum value for *n* of 0 or 1, and a maximum value for *n* of 7 or greater.

Almost all 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. *t* / s or *t* (s).

Most candidates recorded all their raw values of *t* to the nearest 0.01 s or all to the nearest 0.1 s. A small number of candidates added a spurious zero to all their values to give the false impression of greater precision in their measurements.

Raw readings of a quantity should always be recorded to the same precision (the precision of the instrument being used – in this case a stop-watch), and not necessarily to the same number of significant figures.

Most candidates calculated and recorded their values of 1 / *n* correctly. A small number of candidates could not gain credit for their calculation because of incorrect rounding of their final answers.

(d) (i) Most candidates gained credit for drawing appropriate axes for the graph, with labels and sensible scales.

A few candidates chose extremely awkward scales, making the correct plotting of points much more difficult. 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. This invariably makes it very difficult to plot all the points correctly. Candidates using this method cannot gain credit for the scale and often go on to make incorrect read-offs when calculating the gradient or the *y*-intercept of the line. Some candidates chose non-linear scales (e.g. 1/2, 1/3, 1/4 for the 1 / *n* scale), or scales which meant that one or more points were off the graph grid.

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 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. Some candidates plotted points as dots or crosses that were too small to see clearly or were hidden by the line of best fit (a small but clear pencil cross, or a point with a circle, is recommended). Some candidates could improve by plotting the points more accurately, i.e. to within half a small square.

Most 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 joined the first and last points on the graph, regardless of the distribution of the other points, or drew a line which could clearly be improved by rotation. Some candidates were not awarded credit because their lines were kinked in the middle (candidates used too small a ruler), a double line (broken pencil tip) or drawn freehand without the aid of a ruler.

(iii) Many candidates used a suitably large triangle to calculate the gradient, gaining credit for correct read-offs and substitution into $\Delta y / \Delta x$. Other candidates needed to check that the read-offs used were within half a small square of the line drawn, or show clearly the substitution into $\Delta y/\Delta x$ (not $\Delta x/\Delta y$).

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).

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. A point from the table should only be used if the point 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.

The majority of the candidates recorded correct units for *a* and *b* (both s); others omitted the units for *a* and *b*. 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)**.

Question 2

(a) (i) Some candidates measured the value of *d* correctly; others misread the micrometer or recorded a value with insufficient precision.

(ii) Almost all candidates recorded a value for *w* in the appropriate range. A few candidates did not include a consistent unit.

(b) (i) Almost all candidates recorded a value for *x* in the appropriate range. Some candidates were not awarded credit because they recorded a value to the nearest cm, or omitted the unit.

(ii) Almost all candidates recorded a value for *t* in the appropriate range. A few candidates either misread the stop-watch or did not include a unit.

(iii) Candidates were asked to estimate the percentage uncertainty in their value of *t*. Most candidates were familiar with the equation for calculating percentage uncertainties, but many underestimated the absolute uncertainty in the value of *t*. This is dependent not only on the precision of the stop-watch, but also on the possible errors in starting and stopping the stop-watch. A more realistic estimate for the absolute uncertainty in measuring these times is 0.2–0.5 s.

(iv) Almost all candidates calculated the final speed *v* correctly, with consistent units. A few confused units by, for example, using a value for *x* in cm in the calculation but then giving units of $m\,s^{-1}$ on the answer line.

(v) Stronger candidates explicitly linked the significant figures of *v* to the significant figures of *x* and *t*. Others referred only to the 'raw data' without specifying what the raw data is, and so could not be awarded credit.

(c) Most candidates were able to record second values of *w* and *t*, showing the correct trend (*t* should be greater for the wider track).

(d) (i) Many candidates were able to calculate the two values for *k* correctly. Some weaker candidates were not awarded credit because they squared the value for D^2 already calculated in **(a)(ii)** and **(c)**, or used different units for d^2 and D^2.

(ii) Candidates were asked to explain whether their results supported a suggested relationship: allowing for the uncertainties in the measurements, could the two values of *k* be regarded as equal? To do this, candidates need to test the hypothesis against a specified numerical percentage uncertainty, either taken from **(b)(iii)** or estimated themselves. Where candidates state a percentage uncertainty value themselves, 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'. This is not sufficient for credit to be awarded; a numerical percentage comparison is needed.

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

In this experiment, the <u>percentage</u> uncertainty in both *w* and *t* is large because the values of both *w* and *t* are small (it was not sufficient for candidates simply to state that the problem was that '*t* or *w* is small'). Several candidates suggested that the track width may vary along its length.

Some candidates recognised that it was difficult to align the front edge of the sphere with the mark on the track (a parallax error). Others noticed that the sphere sometimes needed a push to set it in motion or, conversely, an unwanted force might be applied when releasing the sphere.

Many candidates suggested repeating the experiment using other track widths and then plotting a suitable graph, or calculating the value of *k* for each experiment and then comparing the values to see if *k* remains constant.

Other valid improvements included using a 'stop' or a card gate to release the sphere from the correct position, using vernier calipers to measure the width of the track, or using a steeper track.

There were several good suggestions made to improve the accuracy of the measurement of *t*, including:

- using a longer slope
- using light gates at the top and bottom of the track to measure *t*
- recording a video of the experiment, then playing back using the video recorder's clock
- using a motion sensor placed in the direction of rolling.

Candidates often find this question difficult to answer well. Generic answers to sources of uncertainty (e.g. 'parallax error' or 'systematic error') do not gain credit without further explanation; candidates should be encouraged to focus their answers on this particular experiment.

Suggestions for improvements also sometimes do not have sufficient detail. Answers such as 'use light sensors' or 'record the experiment on video' are not sufficient. A stronger answer would also state that the light sensors should be connected to a timer with one light sensor placed at the top of the track and the other at the bottom, or the video should be reviewed frame-by-frame, using the video's clock to estimate *t*.

PHYSICS

Paper 9702/35
Advanced Practical Skills 1

Key messages

- Candidates are encouraged to record all their raw data (in the table and elsewhere) to the precision of the instrument used, remembering to include units where appropriate.

- Candidates need to practise plotting and reading off graphs accurately. Graph scales should be chosen so that the plotted points occupy at least half of the graph grid along each axis, but this should not be achieved by selecting an awkward scale that is difficult to use. It is worth double-checking the plotting, especially when a point appears to be anomalous.

- Many candidates find it difficult to draw lines of best fit. To practise and develop this skill, candidates might find it helpful to draw a straight line on a transparent plastic sheet and use it as an overlay, sliding or rotating it to find the line of best fit. A transparent 30 cm ruler and sharp pencil are essential when 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. General points such as 'avoid parallax error' or 'use more precise measuring instruments' will not usually gain credit without further detail. Candidates should be encouraged to write about four different problems and consequently four different solutions to address these problems, and should not try to state four solutions to the same problem.

General comments

There was no evidence that centres had 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.

Successful answers showed the apparatus had been used well, and there were many very good answers. Both questions were attempted by most candidates and there did not seem to be a shortage of time in most cases. Weaker answers in **Question 1** showed that it could be difficult to understand how to arrange the apparatus to give a wide range of x and θ. Before taking any readings, time spent manipulating the apparatus to gain an understanding of how it behaves and the range of angle which could be achieved by changing the height h would be beneficial.

Good practical skills were demonstrated in the generation and handling of data but could be improved by giving more thought to the analysis and evaluation of experiments.

Comments on specific questions

Question 1

(a) Stronger candidates correctly noted a length x_0 which was in the appropriate range and with a correct unit. Good answers had a value of x_0 in the range 0.5 cm $\leqslant x_0 \leqslant$ 2.5 cm.

Weaker candidates often omitted the unit. A unit was not given on the answer line, so for full credit candidates needed to provide a correct unit matching the figure written down.

(b) With the stands correctly arranged, successful candidates correctly stated a value for the angle θ which was less than 90°, with the correct unit of degrees and with raw values to the nearest degree. Weaker answers noted raw values of θ to less than a whole degree.

(c) Strong candidates recorded six sets of readings and included raw values of x and θ, along with extensions e, $e / \cos\theta$ and $\tan\theta$ in neatly presented tables, and the table values showed the correct trend. A number of tables in weaker answers showed confusion in how to arrange the apparatus resulting in an incorrect trend in the data. Weaker answers omitted θ and/or x values from the tables.

The stronger candidates included a large variation in θ values i.e. the largest θ value and the smallest θ value that could be achieved with the apparatus. These candidates varied θ from less than the value measured in **(a)** to a value of θ greater than that measured in **(a)**. Weaker answers often showed a variation in θ where all values were less than that measured in **(a)**.

Strong candidates included a correct quantity and unit in every column heading. Weaker answers omitted units e.g. ($e / \cos\theta$) or did not include a separating mark between the quantity and its unit e.g. $e / \cos\theta$ m or gave the unit of $\cos\theta$ and $\tan\theta$ as degrees e.g. $(e / \cos\theta) / \text{m}^{\circ -1}$ or $(\tan\theta) / {}^{\circ}$.

Consistent answers reflected the precision of the rule used to measure x, so all readings of raw x were given to 0.1 cm, e.g. 15.7 cm or 8.5 cm. Weaker answers noted values to the nearest cm e.g. 16 cm or modified x values by adding a zero in order to make all x values 3 significant figures.

Successful treatment of significant figures was shown when calculated values for $e / \cos\theta$ were recorded to an appropriate number of significant figures from raw data, i.e. to the same number as (or one more than) the number of significant figures in the raw θ or e values, whichever had the smallest number of significant figures. Weaker answers often gave too many significant figures for $e / \cos\theta$.

Many candidates calculated $e / \cos\theta$ correctly. Weaker answers had errors in calculations often caused by incorrect rounding of the final value by truncating rather than rounding.

(d) (i) Stronger candidates used axes for their graphs that were labelled with the appropriate quantities e.g. $e / \cos\theta$ or $\tan\theta$. Weaker answers only stated units or omitted the labels altogether. It is important that candidates select sensible scales. Weaker candidates often used most of the graph grid but did this by using difficult scales, e.g. one large square equal to 0.06 or 0.032. Such scales are very difficult to work with and can cause the candidate to make mistakes in several different places. Better answers used a scale which was easy to interpret with the value of one small square equal to, for example, 0.01. Weaker answers used, for example, 10 small squares equal to 0.15 as then one small square with this scale was worth 0.015.

Some candidates used scales with values missing, e.g. 0.14, 0.18, 0.26 (where 0.22 is missing). Some also had scales where the last value was ‘squashed’ to fit by changing the scale e.g. 0.012, 0.014, 0.016, 0.022.

The strongest candidates had points spreading over more than half the grid. In successful answers with a graph in portrait orientation, points occupied (spread into) six or more large squares in the vertical direction and four or more large squares in the horizontal direction. Weaker candidates often used a scale such that points were squashed into a small area, in some cases just two large squares.

Candidates should take care to plot points within half a small square in both the *x* and *y* directions. Many graphs could be improved by the use of a sharp pencil to draw fine points so that the points have a diameter less than half a small square.

Successful candidates collected data which gave a graph with a negative trend where it was possible to draw a line where all the points lay within ±0.05 of that line.

(ii) Some candidates were able to draw carefully considered lines of best fit, but others 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. 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 (candidates used too small a ruler), a double line (broken pencil tip) or drawn freehand without the aid of a ruler.

(iii) Successful answers clearly showed how to find the gradient and intercept of a straight line graph.

Good gradient calculations used a large triangle, i.e. one for which the hypotenuse was greater than half the length of the drawn line. Weaker gradient calculations used read-offs from a small triangle where the hypotenuse was less than half the drawn line. Good calculations had accurate read-offs substituted correctly into $(y_2 - y_1)/(x_2 - x_1)$ with working that was clear to follow. Some candidates used values from the table that were not on the line rather than taking points from the line.

In finding the intercept, stronger candidates either read off the *y*-intercept directly from the graph where $\tan\theta = 0$ or substituted values for *x* and *y* using a point on the line (not a point from the table) correctly into $y = mx + c$. When rearranging this equation, candidates should obtain $c = y - mx$. Some candidates incorrectly used $c = y / mx$. It was also common for candidates to find the intercept by taking a read-off where the line cut the *y*-axis at a point other than $\tan\theta = 0$, giving a false origin.

(e) Candidates needed to make a direct transfer of values from **(d)(iii)** to **(e)**. *N* was equal to the value of the gradient and *M* was equal to the value of the intercept, and no additional calculations were necessary. Weaker candidates recorded fractions for *N* or *M* or showed fresh substitutions into the equation and further calculations.

Some candidates did not include the units or gave wrong units, such as m / °.

Question 2

(a) (i) Strong candidates who understood how to use the micrometer noted values of raw *d* to the nearest 0.01 mm. Good answers had a final value in the range $0.50\,\text{mm} \leqslant d \leqslant 5.00\,\text{mm}$. Weaker answers often had a final value of 1 mm.

Measuring the diameter *d* with a micrometer was difficult as the micrometer squashed the soft string and this could be stated as a limitation in **(e)**. Successful candidates recognised that this measurement was difficult and noted down repeat readings showing the experiment had been done more than once.

(ii) The absolute uncertainty is not necessarily equal to the value of the smallest division on the scale of the measuring instrument. Many candidates showed repeat readings of *d* reflecting the difficulties involved in this measurement. Consequently, the absolute uncertainty for *d* was greater than 0.01 mm. Weaker answers gave the smallest division on the micrometer, i.e. 0.01 mm. When readings were repeated, some successful candidates showed the absolute uncertainty found by calculating half the range of repeated values.

(iii) Stronger candidates showed the correct substitution of *d* into the equation and a correct calculation of *A* giving the value with a correct consistent unit. Weaker candidates used a unit of mm for *d* and then gave the unit for *A* as m^2 or omitted the unit.

(iv) Candidates needed to be specific and relate the number of significant figures in the value of *d* to the number of significant figures in the value of *A*. Successful answers referred specifically to *d* (i.e. the relevant quantity in this question). Weaker answers stated vague quantities such as 'raw data' or 'values in the calculation', referred to the precision of the ruler or to decimal places, or gave a bald statement such as '3 significant figures'.

(b) (i) Most candidates recorded a value for *p*.

(ii) Most candidates correctly calculated the value of $(p + q)/2$.

(c) Successful answers showed that the experiment had been repeated with the thinner string and second values of *p* and *q* recorded. A thinner string should have produced a smaller value of $(p + q)/2$ if the experiment was carefully carried out. Some weaker candidates found that a thinner string produced a larger value of $(p + q)/2$.

(d) (i) Stronger candidates showed the correct rearrangement of the equation and calculated *k* for both experiments. These answers demonstrated how to rearrange the equation correctly and used $k = [(p + q)/2]^3/A$. If answers showed repeat measurements, successful candidates used the average measurements taking them through into the calculation of *k*. Some weaker candidates rounded in the middle of the calculations and produced inaccurate values.

(ii) Successful candidates had three steps in their argument. They first stated a criterion to be used for testing the relationship. This could be a percentage uncertainty that they think is a sensible limit for this particular experiment, e.g. 5% or 10%, or could be the percentage uncertainty found in **(a)(ii)**. Next they calculated the percentage difference between their values of *k*. Finally, they compared the percentage difference between their *k* values to the percentage uncertainty chosen and decided whether the relationship was supported or not supported. If the percentage difference between the two *k* values was less than the stated criterion, these successful answers then said that the relationship is supported. If the value of the percentage difference is greater than the value of the percentage uncertainty stated as the criterion, then the relationship is not supported. The candidates should make an explicit statement, e.g. 'the relationship is not supported'.

Some candidates did not give any criterion to test against. Many statements were too vague. Some candidates looked at the difference without determining a percentage, or gave an answer that did not logically follow from the data. These did not gain credit.

(e) **Question 2** is designed to have challenges when taking measurements. Often there is other apparatus that could be used to ensure more accurate readings. Successful answers used limitations found while experimenting, stating these in **(i)**. Answers were often improved in **(ii)** by stating a valid method or suggesting specific apparatus that could be used to take more accurate readings. Weaker answers were vague suggesting 'better apparatus'.

Successful candidates stated 'only two thicknesses of string were used to test the relationship and this is not enough to draw a conclusion'. Weaker answers just stated 'two readings are not enough' or 'two sets of readings are not enough to take accurate readings'. To improve this, weaker answers suggested 'taking more readings' or 'taking more readings and find the average' while strong answers correctly suggested 'take more readings and plot a graph'.

The stronger candidates identified genuine limitations. Weaker answers had ideas that were vague or could have been avoided by careful technique, such as zero errors on a metre rule or micrometer, stands which wobbled, wind affecting the movement of mass hangers etc., none of which were valid problems here. Stronger candidates stated that adding paper clips to the mass hanger was difficult as clips would fall off or the hanger was disturbed by the fingers. Weaker answers simply stated that it was 'difficult to add paper clips' without a reason.

While weaker answers suggested it was difficult to know when the hanger moved, stronger answers connected this observation to the idea of increments. Successful answers stated 'the mass of paper clips was too large so it was difficult to determine the exact number needed' or 'the mass required to move the hanger may be less than the mass of one paper clip'. In the improvements section, stronger answers suggested the use of smaller clips or a material such as sand.

The measurement of *d* was difficult but candidates needed to explain the reason for this, e.g. 'it was difficult to measure *d* using a micrometer because the micrometer squashed the soft string when the measurement was taken.' Weaker answers just stated 'it was difficult to measure *d*' without stating a reason and in the improvements section weaker answers suggested 'making *d* larger'. Better answers suggested the use of named, more precise apparatus or clearly described a better method.

Candidates need to suggest detailed limitations and improvements that are specific to this experiment. Statements of general errors e.g. 'systematic errors', 'zero errors' or 'rules with uneven ends' cannot be given credit. Some weaker candidates stated, for example, 'repeat measurements and calculate averages' or included general statements such as 'use an assistant', 'view at eye level' or 'look at right angles to avoid parallax'. Again these statements are not specific enough be given credit, and candidates should be encouraged to give detail that is specific to the particular experiment they are carrying out.

PHYSICS

Paper 9702/36
Advanced Practical Skills 2

Key messages

- Candidates are encouraged to record all their raw data (in the table and elsewhere) to the precision of the instrument used, remembering to include units where appropriate.
- Candidates need to practise plotting and reading off graphs accurately. Graph scales should be chosen so that the plotted points occupy at least half of the graph grid along each axis, but this should not be achieved by selecting an awkward scale that is difficult to use. It is worth double-checking the plotting, especially when a point appears to be anomalous.
- Many candidates find it difficult to draw lines of best fit. To practise and develop this skill, candidates might find it helpful to draw a straight line on a transparent plastic sheet and use it as an overlay, sliding or rotating it to find the line of best fit. A transparent 30 cm ruler and sharp pencil are essential when 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. General points such as 'avoid parallax error' or 'use more precise measuring instruments' will not usually gain credit without further detail. Candidates should be encouraged to write about four different problems and consequently four different solutions to address these problems, and should not try to state four solutions to the same problem.

General comments

There was no evidence that centres had any difficulties in providing the equipment required for use by the candidates, although some centres used springs that were different from the one specified. 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.

The Supervisor's Reports from many centres included useful detail about the apparatus and about difficulties encountered in the experiments. Supervisors rarely had to provide assistance to candidates.

Candidates did not seem to be short of time and all sections of the two questions were answered by almost all the candidates.

Comments on specific questions

Question 1

(a) Most candidates recorded a value of L_0 in the expected range, and included the unit.

(b) Most candidates included the unit with their initial value of θ. In some cases the value implied a precision of 0.1° which was not possible with the protractor provided.

(c) Nearly all candidates recorded six or more sets of values of θ and L. In a few cases, full credit could not be given because each increase in L did not produce an increase in θ.

Candidates were expected to include measurements over the range of values possible with the specified arrangement of apparatus. In some cases the readings did not reach the higher end of the range. Candidates should be reminded that it is important to make maximum use of the apparatus available in order to obtain as wide a range of readings as possible.

Most tables had column headings with the quantity and an appropriate unit. The only common error was to give a unit (usually °) for the $\sin\theta\cos\theta$ column.

The calculated values of $\sin\theta\cos\theta$ were nearly always correctly rounded to an appropriate number of significant figures, which could vary down the column (e.g. one or two s.f. when θ = 7°, and two or three s.f. when θ = 25°).

A small number of candidates recorded only $\sin\theta\cos\theta$ and omitted the measured values for θ. Candidates should be reminded that they must record all of their raw data. It is not possible, for example, for the examiner to check or award credit for correct calculations if the raw data are not shown.

(d) (i) Many graphs were drawn to a very good standard, with accurate and clear plotting of the correct quantities and good use of the available grid area. Most scales were simple with divisions clearly labelled. In a few cases the points were drawn using dots that were too large. The clearest graphs used small crosses.

The quality of the candidates' data was judged by the scatter of points about a straight-line trend, and in the majority of cases this was good and credit was awarded.

(ii) Stronger candidates drew suitable lines of best fit which had a balanced distribution of points either side along the entire length. In some cases, a stray point was apparently ignored without explanation.

(iii) Nearly all candidates knew how to find the gradient of their line. Most candidates took well-spaced values from their line, carried out the procedure accurately and showed their working clearly. The intercept value was often negative and so it could not be read directly off the $(L - L_0)$ axis. Candidates generally knew how to calculate the intercept using their gradient value.

(d) Most candidates recognised that a was equal to the value of the gradient and b was equal to the intercept, although some rounded their value of a to only one significant figure. Other candidates had difficulty determining the units (which were cm or m for both a and b) and some omitted units altogether.

Question 2

(a) The apparatus was simple and few problems were reported with setting up the apparatus. The measurement h_0 from the blade to the floor usually gained credit. In a very few cases, no unit was given or the value was not recorded to the nearest mm.

(b) (i) The measurement of the blade height h after adding a load was awkward to carry out because of the obstruction caused by the load. However, most candidates recorded sensible values.

(ii) Most candidates correctly calculated the change y produced when the load was added.

(c) There were some good answers for the percentage uncertainty in y. The use of an absolute uncertainty of 3 mm or more was expected given the various problems with taking this measurement. Smaller uncertainties were unrealistic when considering the difficulty in measuring h.

Some candidates looked at the spread of repeated readings and used half the range of these values, which is another valid method that was awarded credit.

(d) The majority of candidates used an appropriate timing procedure, for example timing 5*T* several times and then using these values to calculate *T*.

The value of *T* in this experiment was less than a second. Some weaker candidates recorded a value around 5 s on the answer line, and in these cases it is likely that they had timed 5*T* (for example) and not divided the answer by 5.

Some candidates counted the number of oscillations in a fixed time of 10 s. This is an unsatisfactory method as it gives less accuracy in the final *T* value.

(e) Most candidates correctly repeated the experiment after repositioning the load. When the load was moved as instructed it should have resulted in a larger value for *T*. In a small number of cases, *T* was smaller and this suggests the instructions were not followed correctly.

(f) (i) The calculation of *c* was correct for nearly all candidates.

(ii) The discussion of whether the analysis in **(f)(i)** supported the suggested relationship was carried out well by many candidates.

Unsuccessful answers usually did not have a numerical comparison of the percentage difference of the *c* values with what would be an acceptable difference in this experiment. General or vague statements such as 'it is valid because the values are close to each other' cannot be awarded credit.

Candidates should be encouraged to ensure their justifications are quantitative in nature. One possible method is to refer back to the percentage uncertainty in **(c)** although only a small number of candidates chose to use this method.

(g) The calculation of a value for *g* was generally correct numerically. In a number of cases, the unit was inconsistent with the calculated value. For example, some candidates had used a value for *y* in cm but gave the unit for *g* as the more familiar $\mathrm{m\,s^{-2}}$ (instead of $\mathrm{cm\,s^{-2}}$).

(h) 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 how these difficulties impact on the experiment. Candidates should then try to think of associated solutions that address each of these problems.

Many candidates identified the major problems encountered in this particular experiment: the problems with taking the blade height measurements and with timing the blade vibrations. Most identified as a problem that the rule might not be vertical, and stronger candidates went on to suggest a practical solution, e.g. using a set square between the floor and the rule.

The fact that h_0 would vary with the position along the blade if the blade was not horizontal was identified by many candidates, but very few went on to suggest that the measurement should be taken at the place where the mass would be attached. The difficulty with measuring *h* caused by the presence of the mass was also often identified (usually in terms of parallax error due to the rule being held at a distance from the blade), and a few candidates suggested an improved procedure, e.g. using a pointer.

Many candidates were concerned about the short time period of the vibrations, and most of these gave the necessary further detail, e.g. it made it difficult to count the oscillations. The usual suggestion for an improvement was to take a video with a timer in view so that the movement could be viewed and timed in slow motion.

Some responses were not credited as they would not actually result in an improvement, e.g. blade not released from same point or with same force (neither of these would affect the vibration period). Credit was also not given for suggested improvements that could have been carried out in the original experiment, such as 'repeat measurements', 'do more readings to get an average value' or 'ensure reading is taken perpendicularly'.

PHYSICS

Paper 9702/41
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 be careful that they do not give more than one answer to a question. If multiple answers are provided that are contradictory, the candidate cannot be awarded credit for a correct answer.
- 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 the use of correct physics, it is often possible to receive some credit even when the final answer is incorrect.

General comments

In general terms, candidates performed well on traditional questions involving 'bookwork' and not as well on questions requiring application of knowledge. Working was nearly always shown, and the use of English was good in general and better than in previous series. Candidates should be encouraged to provide explanations when asked to 'explain your working' as some of the credit for the answer will depend on the explanation.

Comments on specific questions

Question 1

(a) (i) The ratio of work done per unit mass was not stated on many responses. Most candidates understood the idea of moving the mass from infinity.

(ii) Candidates wrote mostly about gravitational field strength and radial field lines rather than gravitational potential. A small number incorrectly introduced the idea of the very large mass of the Earth.

(b) This calculation proved to be difficult. A common error that gained partial credit was to use the diameter instead of the radius. Another common misconception was to attempt to apply formulae for circular motion.

Question 2

(a) While there were many good statements on the meaning of internal energy, some candidates did not refer to molecules but instead to the system as a whole. A few candidates quoted the first law of thermodynamics. Credit could not be awarded for these responses.

(b) (i) Many candidates were awarded credit for the idea of no change in internal energy, but few could link this to the explanation of there being no change in temperature.

(ii) Many tables were completed correctly. A large number of candidates gained partial credit by 'error carried forward', completing the table consistently even though some of the values were not correct.

Question 3

(a) Many candidates were able to extract information from the graph successfully and complete this calculation. A few candidates omitted the square in the expression $\omega^2 = 2g / l$ and a few did not convert the length from cm into m.

(b) (i) Many responses here suggested that the air or the atmosphere was responsible for the damping effect. Some responses were vague and did not say where the friction was acting.

(ii) Candidates were generally successful in this question. There were occasional errors with unit conversions from cm into m, the use of 2.5 s as the time period and the use of gravitational potential energy.

Question 4

(a) Some candidates are unable to explain the principles behind the use of ultrasound to obtain diagnostic information. It is often not clear from the responses that pulses of ultrasound are used and that the reflection occurs at boundaries between two media. A relatively small number of candidates explained the production of ultrasound, but this could not be awarded credit because the question was focused on the *use* of ultrasound, not how it is produced.

(b) (i) The definition of specific acoustic impedance was well known. A very small number of candidates incorrectly referred to the speed of light.

(ii) Only the strongest candidates were able to answer this question correctly. Many candidates quoted the intensity reflection coefficient equation and then tried to state the equation in words. Many did not show that they understood the relevance of the difference between the two specific acoustic impedances.

Question 5

(a) There were many correct advantages stated here. A common misconception involved noise. Noise is present in digital signals and candidates should take care not to imply that there is no noise. The advantage of digital transmission is that the noise may be eliminated from the data.

(b) There were many good answers to show the signal level from the DAC. Some candidates did not include a scale on the time axis or made a power-of-ten error in labelling the axis.

(c) It was common to see answers involving the improved quality of the analogue signal. It is true that a greater number of bits and greater sampling rate will improve signal fidelity. However, candidates needed to use more detail and could have made their answers clearer by referring to the graph in Fig. 5.2. Some candidates did not seem to be aware that the decoded analogue signal is not continuously variable but in steps.

Question 6

(a) (i) The ratio of work done per unit charge was not stated on many responses. Some candidates did not convey the idea of moving the positive charge from infinity.

(ii) There were very few correct answers. It was common to see the incorrect assertion that field strength and potential are directly proportional.

(b) (i) Many candidates appreciated that electrical potential energy was being converted to kinetic energy but did not show that speed does not depend on separation. The easiest way to explain this was to write an expression equating PE and KE for this situation and then to rearrange it to give speed *v*. This clearly demonstrated that separation was irrelevant.

(ii) Many responses did not appreciate that the helium nucleus had only accelerated through a p.d. of 25 V. Most candidates did then successfully complete the rest of the calculation using the formula $qV = ½mv^2$.

Question 7

(a) (i) The meaning of the term *infinite bandwidth* was not generally well known.

(ii) The meaning of the term *infinite slew rate* was more commonly known.

(b) Most candidates completed the circuit diagram correctly. A common mistake was to connect the midpoint of the resistors to earth as well as to the inverting input V^-.

(c) (i) This question was well answered.

(ii) Some candidates did not realise that the op-amp would be saturated in this situation.

Question 8

(a) Many good answers were given here. A common mistake was to state that the force was on a mass or to omit what the force acts on. Another common mistake was to write that the force was on ‘a charge’ without making clear that the charge must be moving.

(b) (i) Candidates generally drew good diagrams. A common error was to continue the curved path once the particle had left the region of the magnetic field.

(ii) Candidates found this question difficult. Some candidates stated that there was no change in speed because the force is centripetal, but without explaining what centripetal meant. A common error was to state that the force was ‘normal’ but without making clear that it is normal to the direction of motion.

(c) The weakest candidates often thought that the centripetal force would be the same in both cases so that $Bqv_1 = B(2q)v_2$ giving $v_2 = ½v_1$.

Many candidates knew that the centripetal force was provided by the magnetic force and could introduce the expression $Bqv = mv^2 / r$ but then could not proceed further. Only the stronger candidates knew that, if the path was unchanged, the radius would be unchanged and so could proceed to a valid final answer of $v_2 = 2v_1$.

Question 9

(a) The majority of candidates gave correct answers here. Weaker candidates used 'electromagnetic force' or 'electromagnetic induction' in place of 'electromotive force', or omitted the word 'rate' from their answers.

(b) (i) A common incorrect answer to this question was 0.026 V, as candidates forgot that the change in the flux density was 0.38 T and not 0.19 T.

(ii) Some candidates gave non-zero values for the voltage across coil C for both before and after the current was changing, indicating they did not fully understand Faraday's law.

The majority of candidates knew that the Hall probe would not produce a voltage when the current was zero. Some candidates omitted the negative sign for the Hall probe's voltage after the current had changed.

Question 10

Most candidates had at least a basic idea of band theory. Candidates generally understood that electrons are promoted and that this leaves holes. Only a small number of candidates mentioned the increase in the number of charge carriers leading to a decrease in resistance, and only a small number explained the effects of the increased lattice vibrations.

Question 11

(a) The definition of the photon was generally well known. There were some errors due to omitting the word energy.

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

(ii) This calculation was also well answered.

(c) (i) This calculation was also well answered.

(ii) The idea of the principle of conservation of momentum applying to a photon did not seem to be familiar to some candidates. Many answers were written in terms of energy rather than momentum.

Question 12

(a) Candidates found this question difficult. Some referred to fission or nuclei splitting, and some candidates had difficulty finding words to describe emission.

(b) (i) Candidates generally realised that they had to find the gradient of the graph at t = 4.0 hours and then use that to find the activity. This was well answered. There were some errors due to the units on the axes of the graph. Candidates should be reminded that, where the question asks for a particular method to be used (in this case the gradient of the line), they should use this method and should not attempt to determine the answer using other methods.

(ii) Some candidates did not follow the instruction to use the answer in **(i)**, and instead attempted to find the answer using $\lambda = \ln 2 / t_{½}$. Many responses did not obtain the required numerical value. When this occurs in a 'show that' question, candidates need to look for their mistake in this or a previous calculation.

(c) All but the very weakest candidates started with the correct formula $A = A_0 e^{-\lambda t}$, and substituted in the values correctly. It was more difficult to successfully manipulate the expressions to arrive at a correct storage time in seconds. Mistakes in converting this time from seconds to days were comparatively rare.

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 be careful that they do not give more than one answer to a question. If multiple answers are provided that are contradictory, the candidate cannot be awarded credit for a correct answer.
- 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 the use of correct physics, it is often possible to receive some credit even when the final answer is incorrect.

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 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 be award partial credit.

Comments on specific questions

Question 1

(a) (i) Most candidates correctly defined gravitational field strength as force per unit mass. Some candidates answered a question asking about the meaning of a gravitational field rather than the question that was asked.

(ii) Very few candidates answered the question that was asked. Those who did were able to explain that both quantities (acceleration of free fall and gravitational field strength) were given by the ratio force/mass and that hence the two quantities are numerically equal. However, many candidates gave a response to a question asking about the effect of small changes in height above the surface of a planet on its gravitational field strength. This illustrates clearly the importance of reading the question carefully and answering the question asked, and of the dangers of an approach that relies on memorising previous mark schemes.

(b) Many candidates drew acceptable curves. Common mistakes were starting the curve at $x = 0$ rather than $x = R$, and thinking that the variation of acceleration with x was inverse rather than inverse-square.

(c) Most candidates were able to calculate the mass of the planet using the correct equations for density and for the volume of a sphere. Many candidates did not realise that a point at height R above the surface is at a distance $2R$ from the centre of the planet. As a result, an incorrect final answer of $3.8\,\mathrm{m\,s^{-2}}$ was common.

Question 2

(a) Most candidates stated that an ideal gas is one for which pV/T is constant, but most did not identify the meaning of these symbols. Some candidates stated that an ideal gas is one that obeys the ideal gas equation, without stating what that equation is. It was common for candidates to give assumptions of the kinetic theory rather than the defining equation of an ideal gas.

(b) (i) Most candidates (correctly) started by quoting the relationship $pV = (1/3)Nm\langle c^2\rangle$ from the formula sheet. The key to answering the question correctly was to appreciate the meaning of the symbols in this equation. It is always important, when dealing with ideal gases, that candidates are careful with quantities n, N, m and M. Confusion of number of particles with number of moles, or of mass of gas with mass of a particle, is a common source of mistakes. Candidates needed to appreciate that the quantity Nm (number of particles × mass of a particle) equates to the mass of the gas. A common error was to take N to be the Avogadro constant and m to be the mass of the gas. Another common error was to consider the gas as consisting of one particle of mass 3.2 kg.

Of candidates who correctly calculated the mean square speed, some either forgot to take the square root or believed that they had found the r.m.s. speed. Finally, some candidates overlooked the instruction to give the answer to three significant figures.

(ii) 1. This question was generally well answered, although the three significant figure instruction was sometimes overlooked. A small number of candidates made the mistake of leaving the temperature in °C.

2. This question proved to be more challenging to candidates, with many not appreciating that the answer to **part 1** multiplied by the Avogadro constant gives the number of particles and that this figure, divided into the mass of the gas, gives the mass of a particle.

An approach that divided the answer to **part 1** by the unified atomic mass unit was common, despite the fact that this approach yielded an answer of the order of 10^{29} kg. Candidates should be able to detect that a mistake has been made when an answer of this magnitude is obtained.

(c) Very few candidates answered this question correctly. Of those who did use the correct approach, it was common for candidates not to realise that A must be an integer.

Question 3

(a) Whilst most candidates appreciated that the energy transfer involved relates to the solid/liquid state change at constant temperature, only a few gave a dimensionally correct answer that defined specific latent heat as an energy per unit mass.

(b) (i) There were many ways in which candidates could answer this question, and all of them were seen correctly used. In essence, candidates needed to correctly identify a quantity relating to the water entering the beaker (such as change in mass, change in volume or number of drops) and to relate this to being constant in a constant time interval. Common incorrect answers were those that focused on the meter readings (which relate to the rate at which electrical energy is supplied, not to the rate at which the ice is melting) or that re-stated the question (by focusing on the ice melting rather than the water being collected).

(ii) Many candidates were able to calculate values that were equivalent to the electrical power supplied and to the rate of transfer of energy to the ice. However, it was common for candidates to confuse which power was which. Consequently, 58.9 W was commonly given as the answer to **part 1**, and 70.3 W was commonly given as the answer to **part 2**.

Question 4

(a) Candidates needed to give $a \propto -x$ as the defining equation of simple harmonic motion, and then to comment that the equation given in the question corresponds to this defining equation on the grounds that g and L are constant. It was common for candidates to present numerous algebraic expressions linking a and x, but without any commentary about the significance of constants within those expressions it was not possible to gain credit. Some candidates described the two defining characteristics of simple harmonic motion but did not link them to the equation given.

(b) This question was generally well answered, with many candidates being awarded full credit. The most common error was to equate $2g/L$ with ω (rather than ω^2) as the starting point.

(c) (i) A significant number of candidates attributed the damping to either gravity or atmospheric pressure. The other common error was to describe the consequence of damping (loss of energy) rather than the cause of it. Descriptions of ‘friction’ were allowed, provided it was clear where this friction acted. The best answers made direct reference to viscous forces.

(ii) Candidates found this a challenging question, but stronger candidates were able to deduce a correct expression for total energy and to read off the initial amplitude from the graph. Of these candidates, the most common error was to take 3 oscillations rather than 1.5, and therefore to use 0.85 cm as the final amplitude.

Question 5

(a) Candidates who knew the ‘bookwork’ were able give good explanations of amplitude modulation. This is an example of a question where it is important to use technical language accurately. Common errors were to confuse amplitude and displacement, and to confuse the carrier wave with the information signal. It is also important to stress that, when explaining the meaning of a term, candidates cannot rely on the use of a word in that term in their explanation. In this case, answers that explained ‘amplitude modulation’ in terms of the amplitude being ‘modulated’ could not be awarded credit without it being clear that ‘modulated’ means ‘varied’.

(b) (i) A significant number of candidates did not realise that the modulated wave has the same frequency as the carrier wave. Accordingly, it was common to see frequencies of 5 kHz, 895 kHz or 905 kHz used in the calculation.

(ii) Only a minority of candidates were able to correctly describe the variation of amplitude. Some answers referred to an increase or a decrease but did not convey repeated alternation between the two. Others referred to a maximum and a minimum but did not describe the variation between them. A significant number of candidates restated their answer to **(a)**.

(iii) Many candidates found this question difficult, with 5 kHz being a common wrong answer. Some candidates gave 10 Hz. Candidates should be advised that, where a unit such as Hz is printed on the answer line, it is acceptable for them to give their answer in kHz, but in doing so they must make the unit clear (either by writing kHz after the answer, or by adding a 'k' prefix to the printed unit).

(c) (i) The characteristic features of a geostationary orbit were generally well known, with many candidates receiving full credit here. Some candidates missed the caveat 'apart from period' in the question line. Others confused discussion of the orbit with the position of a satellite in that orbit; answers that simply paraphrased 'geostationary' could not be awarded credit.

(ii) 1. Most candidates made no reference to the effect of the atmosphere (or ionosphere) on the propagation of the signals.

2. Candidates needed to discuss the 'swamping' effect of the downlink signal on the uplink as a result of the high attenuation of the uplink and/or the high amplification of the downlink. Many answers were too vague in their description of the role played by each signal. For example, answers referring to 'preventing swamping of the uplink and the downlink' were common. Other candidates confused swamping with interference or discussed noise/crosstalk.

Question 6

(a) (i) The first marking point required candidates to give a dimensionally correct definition for the magnitude of electric potential, as a work done per unit charge. Many candidates did not do this, and instead gave definitions that had the dimensions of energy rather than potential. The second marking point required candidates to give a definition that yielded the correct sign – most commonly by referring to the work done in moving positive charge from infinity. More candidates were successful in this.

(ii) Many candidates gave equations for the electric field strength and electric potential due to a point charge, but this did not answer the question. Answers that actually attempted to give a relationship between electric field strength and electric potential were relatively uncommon. Candidates were expected to state that electric field strength = – potential gradient, but only a small number of candidates could do this.

(b) Whilst most candidates were awarded at least partial credit for this question, few fully understood the potential variation within and between the spheres. Many candidates confused potential with field strength. This confusion often resulted in graphs that showed the potential to be zero within the spheres and/or crossing into the negative region at some point between the spheres. For candidates who did realise that the potential remains positive all the way across, the details (of the minimum being nearer to B than to A, and the fact that the minimum does not dip to zero potential) were often missed.

Question 7

(a) Most candidates were able to read the value of 3.2 kΩ from the graph for the resistance of the thermistor at 4 °C. Application of this to the potential divider arrangement to correctly deduce the value of *R* proved more challenging to many candidates. Among the candidates that did do this successfully, the method chosen was often unnecessarily complicated, with only a small number of candidates realising that the ratio R_T / R had to be equal to the ratio 1.8 / 2.4.

(b) There were many good answers to this question. Most candidates were awarded the first mark, for identifying that the resistance of the thermistor increases (or reading its value from the graph). The effect of this on the potentials at the inverting and non-inverting inputs then had to be deduced, leading to a conclusion that the output saturates positively. Candidates who did not appreciate that the op-amp is acting as a comparator often treated it as an inverting amplifier and attempted to compare input and output potentials rather than comparing the two inputs. It was not possible to obtain credit for a correct conclusion without that conclusion being justified in terms of the input potentials.

(c) Most candidates were awarded credit for showing two LEDs connected in parallel between V_{OUT} and earth facing in opposite directions. Fewer correctly identified which was G and which was B (which had to be consistent with the conclusion given in **(b)**). The number of candidates that did not know the circuit symbol for an LED was greater than expected.

Question 8

(a) Many candidates were awarded credit for either 'force per unit length' or 'force per unit current', but very few candidates gave a definition that correctly included both elements of the ratio. Many answers contained vague references to 'perpendicular', but this was often in relation to the direction of the force. For the third mark it had to be clear that the current (or the length of the conductor) is at right angles to the magnetic field.

(b) Many candidates gave answers in terms of 'currents' or 'fields' cancelling, but the number that correctly discussed the forces on the two sections was small. Confusion with electromagnetic induction was widespread, with candidates frequently concluding that, because no flux is cut, there is no force (induced) on the wires.

(c) Only the strongest candidates appreciated that the starting point for answering this question is to apply the principle of moments to the turning effects caused by the weight of the mass and the force on QR about the pivot. Of the candidates that did realise this, common mistakes were omission of *g* (leading to use of the mass rather than the weight of the small mass) or an incorrect conversion of the mass of the small mass into kg.

Question 9

(a) Many candidates drew graphs that were fully correct. A common misunderstanding was that the sign of V_H had to stay positive and did not change when the direction of *B* changed.

(b) Fewer candidates appreciated that, whilst the Hall probe in **(a)** produces a Hall voltage that is proportional to *B*, the small coil in **(b)** works on the basis of electromagnetic induction and therefore produces an induced e.m.f. that is proportional to the *rate of change* of *B*. Fully correct answers to **(b)** were relatively uncommon.

Question 10

(a) Although many candidates correctly calculated the peak voltage, most did not calculate the angular frequency. Most candidates who did calculate these values were able to go on to substitute them correctly into the sinusoidal wave equation for *V* in terms of *t*.

(b) It was common to see responses that addressed the function of the large constant magnetic field with an explanation of how NMRI works. Candidates that answered the question asked, and addressed the function of the non-uniform magnetic field, were often awarded at least partial credit.

(c) Most candidates were able to make a start by quoting the correct exponential equation for the attenuation of intensity. When applying this equation to the compound structure, it was common for candidates to try to add the effects on intensity of the separate layers, rather than to multiply them. This misconception restricted access to the later marks. Candidates who arrived at a ratio for I/I_0 were still able to gain credit for converting this ratio to decibels, even if the ratio itself was incorrect. However, many candidates stopped short of taking this final step.

Question 11

(a) Most candidates correctly identified a photon as a quantum of energy. However, the identity of this energy as being electromagnetic was often confused. Many candidates thought that electromagnetic radiation 'carries' or 'emits' photons, rather than appreciating that the photons *are* the electromagnetic radiation.

(b) Very few candidates answered the question asked by attempting to describe an appearance. Most candidates instead gave an explanation of how an emission spectrum is formed. Many of these descriptions were very good, but unfortunately they could not be awarded credit because they did not answer the question. Of those answers that did describe an appearance, common mistakes were to confuse with electron diffraction (and describe concentric circles) or to confuse with two-slit diffraction (and describe alternate light and dark fringes).

(c) (i) Only a small number of candidates gave the correct number. A common incorrect answer was 3, presumably because the possibility of losing energy in multiple stages was overlooked.

(ii) 1. A minority of candidates appreciated that maximum kinetic energy was produced from the –0.85 eV to –13.5 eV transition and deduced the photon energy accordingly before subtracting the work function.

2. The starting equation was generally well known, but most candidates used their answer to **part 1** rather than the photon energy in carrying out the calculation.

Question 12

(a) Although most candidates realised that fusion is to do with joining together and fission is to do with splitting, many otherwise good answers were spoilt by incorrect use of technical terminology. Candidates should know that it is nuclei (not atoms, molecules, nuclides or nucleons) that are involved in these processes and use the terms correctly. It is also important that candidates are clear whether they are talking about one nucleus or multiple nuclei; the use of 'nuclei' to represent both the singular and the plural made many responses ambiguous. Examiners were able to give benefit of doubt where the context made the intention of the candidate clear, but there were cases where this was not possible.

This question also illustrates the principle highlighted in the report on **Question 5(a)**, that reliance cannot be placed on words that the question is asking candidates to explain. When describing what is meant by 'fusion', candidates cannot be awarded credit just for stating that nuclei 'fuse'; there is a need to explain what that term means. Some indication of combining or joining together was expected. The common misconception with fission was to confuse with radioactive decay.

(b) (i) Most candidates deduced correctly that particle x is a neutron. Common incorrect answers included proton, beta-particle, photon and antineutrino. The number of candidates who knew the identity of the particle but who did not name it (instead only giving its symbol) was small.

(ii) Most candidates found this question difficult. Many did not realise that the binding energy of a single particle must be zero. In **part 2**, the number of candidates who did not multiply the binding energies per nucleon by the nucleon number was greater than expected given that this is normally a fairly routine procedure during the study of the topic of binding energy.

(iii) Only the strongest candidates received credit. It was expected that candidates would either realise or deduce that the masses given of deuterium and tritium correspond to 1 mole, and that therefore the number of helium nuclei produced was equal to the Avogadro constant. The answer expected was therefore the answer to **(b)(ii) part 2** multiplied by the Avogadro constant. Weaker candidates either just replicated their answer to **(b)(ii) part 2** or omitted the question.

PHYSICS

Paper 9702/43
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 be careful that they do not give more than one answer to a question. If multiple answers are provided that are contradictory, the candidate cannot be awarded credit for a correct answer.
- 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 the use of correct physics, it is often possible to receive some credit even when the final answer is incorrect.

General comments

In general terms, candidates performed well on traditional questions involving 'bookwork' and not as well on questions requiring application of knowledge. Working was nearly always shown, and the use of English was good in general and better than in previous series. Candidates should be encouraged to provide explanations when asked to 'explain your working' as some of the credit for the answer will depend on the explanation.

Comments on specific questions

Question 1

(a) (i) The ratio of work done per unit mass was not stated on many responses. Most candidates understood the idea of moving the mass from infinity.

(ii) Candidates wrote mostly about gravitational field strength and radial field lines rather than gravitational potential. A small number incorrectly introduced the idea of the very large mass of the Earth.

(b) This calculation proved to be difficult. A common error that gained partial credit was to use the diameter instead of the radius. Another common misconception was to attempt to apply formulae for circular motion.

Question 2

(a) While there were many good statements on the meaning of internal energy, some candidates did not refer to molecules but instead to the system as a whole. A few candidates quoted the first law of thermodynamics. Credit could not be awarded for these responses.

(b) (i) Many candidates were awarded credit for the idea of no change in internal energy, but few could link this to the explanation of there being no change in temperature.

(ii) Many tables were completed correctly. A large number of candidates gained partial credit by 'error carried forward', completing the table consistently even though some of the values were not correct.

Question 3

(a) Many candidates were able to extract information from the graph successfully and complete this calculation. A few candidates omitted the square in the expression $\omega^2 = 2g / l$ and a few did not convert the length from cm into m.

(b) (i) Many responses here suggested that the air or the atmosphere was responsible for the damping effect. Some responses were vague and did not say where the friction was acting.

(ii) Candidates were generally successful in this question. There were occasional errors with unit conversions from cm into m, the use of 2.5 s as the time period and the use of gravitational potential energy.

Question 4

(a) Some candidates are unable to explain the principles behind the use of ultrasound to obtain diagnostic information. It is often not clear from the responses that pulses of ultrasound are used and that the reflection occurs at boundaries between two media. A relatively small number of candidates explained the production of ultrasound, but this could not be awarded credit because the question was focused on the *use* of ultrasound, not how it is produced.

(b) (i) The definition of specific acoustic impedance was well known. A very small number of candidates incorrectly referred to the speed of light.

(ii) Only the strongest candidates were able to answer this question correctly. Many candidates quoted the intensity reflection coefficient equation and then tried to state the equation in words. Many did not show that they understood the relevance of the difference between the two specific acoustic impedances.

Question 5

(a) There were many correct advantages stated here. A common misconception involved noise. Noise is present in digital signals and candidates should take care not to imply that there is no noise. The advantage of digital transmission is that the noise may be eliminated from the data.

(b) There were many good answers to show the signal level from the DAC. Some candidates did not include a scale on the time axis or made a power-of-ten error in labelling the axis.

(c) It was common to see answers involving the improved quality of the analogue signal. It is true that a greater number of bits and greater sampling rate will improve signal fidelity. However, candidates needed to use more detail and could have made their answers clearer by referring to the graph in Fig. 5.2. Some candidates did not seem to be aware that the decoded analogue signal is not continuously variable but in steps.

Question 6

(a) (i) The ratio of work done per unit charge was not stated on many responses. Some candidates did not convey the idea of moving the positive charge from infinity.

(ii) There were very few correct answers. It was common to see the incorrect assertion that field strength and potential are directly proportional.

(b) (i) Many candidates appreciated that electrical potential energy was being converted to kinetic energy but did not show that speed does not depend on separation. The easiest way to explain this was to write an expression equating PE and KE for this situation and then to rearrange it to give speed *v*. This clearly demonstrated that separation was irrelevant.

(ii) Many responses did not appreciate that the helium nucleus had only accelerated through a p.d. of 25 V. Most candidates did then successfully complete the rest of the calculation using the formula $qV = \frac{1}{2}mv^2$.

Question 7

(a) (i) The meaning of the term *infinite bandwidth* was not generally well known.

(ii) The meaning of the term *infinite slew rate* was more commonly known.

(b) Most candidates completed the circuit diagram correctly. A common mistake was to connect the midpoint of the resistors to earth as well as to the inverting input V^-.

(c) (i) This question was well answered.

(ii) Some candidates did not realise that the op-amp would be saturated in this situation.

Question 8

(a) Many good answers were given here. A common mistake was to state that the force was on a mass or to omit what the force acts on. Another common mistake was to write that the force was on 'a charge' without making clear that the charge must be moving.

(b) (i) Candidates generally drew good diagrams. A common error was to continue the curved path once the particle had left the region of the magnetic field.

(ii) Candidates found this question difficult. Some candidates stated that there was no change in speed because the force is centripetal, but without explaining what centripetal meant. A common error was to state that the force was 'normal' but without making clear that it is normal to the direction of motion.

(c) The weakest candidates often thought that the centripetal force would be the same in both cases so that $Bqv_1 = B(2q)v_2$ giving $v_2 = \frac{1}{2}v_1$.

Many candidates knew that the centripetal force was provided by the magnetic force and could introduce the expression $Bqv = mv^2 / r$ but then could not proceed further. Only the stronger candidates knew that, if the path was unchanged, the radius would be unchanged and so could proceed to a valid final answer of $v_2 = 2v_1$.

Question 9

(a) The majority of candidates gave correct answers here. Weaker candidates used 'electromagnetic force' or 'electromagnetic induction' in place of 'electromotive force', or omitted the word 'rate' from their answers.

(b) (i) A common incorrect answer to this question was 0.026 V, as candidates forgot that the change in the flux density was 0.38 T and not 0.19 T.

(ii) Some candidates gave non-zero values for the voltage across coil C for both before and after the current was changing, indicating they did not fully understand Faraday's law.

The majority of candidates knew that the Hall probe would not produce a voltage when the current was zero. Some candidates omitted the negative sign for the Hall probe's voltage after the current had changed.

Question 10

Most candidates had at least a basic idea of band theory. Candidates generally understood that electrons are promoted and that this leaves holes. Only a small number of candidates mentioned the increase in the number of charge carriers leading to a decrease in resistance, and only a small number explained the effects of the increased lattice vibrations.

Question 11

(a) The definition of the photon was generally well known. There were some errors due to omitting the word energy.

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

(ii) This calculation was also well answered.

(c) (i) This calculation was also well answered.

(ii) The idea of the principle of conservation of momentum applying to a photon did not seem to be familiar to some candidates. Many answers were written in terms of energy rather than momentum.

Question 12

(a) Candidates found this question difficult. Some referred to fission or nuclei splitting, and some candidates had difficulty finding words to describe emission.

(b) (i) Candidates generally realised that they had to find the gradient of the graph at t = 4.0 hours and then use that to find the activity. This was well answered. There were some errors due to the units on the axes of the graph. Candidates should be reminded that, where the question asks for a particular method to be used (in this case the gradient of the line), they should use this method and should not attempt to determine the answer using other methods.

(ii) Some candidates did not follow the instruction to use the answer in **(i)**, and instead attempted to find the answer using $\lambda = \ln 2 / t_{½}$. Many responses did not obtain the required numerical value. When this occurs in a 'show that' question, candidates need to look for their mistake in this or a previous calculation.

(c) All but the very weakest candidates started with the correct formula $A = A_0 e^{-\lambda t}$, and substituted in the values correctly. It was more difficult to successfully manipulate the expressions to arrive at a correct storage time in seconds. Mistakes in converting this time from seconds to days were comparatively rare.

PHYSICS

Paper 9702/51
Planning, Analysis and Evaluation

Key messages

- Candidates should be encouraged to read the questions carefully before answering them to understand what is required. Planning a few key points before commencing **Question 1** is useful.
- 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. Candidates should take care 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. 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.

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. There were some unworkable setups shown in diagrams. A very large number of candidates did well on the analysis section with clear identification of how the constants could be determined. Many candidates did not provide enough additional detail. 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 and *y*-intercept of a graph. For a number of 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. Some candidates did not realise that there was a false origin and so the *y*-intercept could not be read directly from the *y*-axis.

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

Comments on specific questions

Question 1

The majority of the 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. Many candidates stated that the density of the salt solution needed to be kept constant. Some candidates produced a list of quantities which were either not relevant to the equation or not appropriate, e.g. mass of salt, volume of water, initial temperature of solution. A small but significant number of candidates use the incorrect term 'control' rather than the correct term 'constant'.

Additional detail marks were awarded for candidates who stated how the density of the salt solution could be calculated and how it could be determined by making appropriate measurements. Candidates were expected to describe measuring the volume of the salt solution with a measuring cylinder and determining the mass by finding the difference in balance readings – many candidates did not indicate there was a mass difference to be taken. Some candidates correctly mentioned to tare the balance. Credit was not awarded for suggesting a graduated beaker. Candidates should be encouraged to define symbols in any equation that is used.

Credit is available for the method of data collection. 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 how the pressure could be changed. Stronger candidates clearly showed that the system was sealed and attached to a pump. In addition, candidates needed to label the 'salt solution' on the diagram.

A workable method of heating the salt solution was required. The more desirable electrical methods of heating were seen but were much less common than using a Bunsen burner. A sealed flask heated by a labelled Bunsen burner gained credit. Candidates did not gain credit for giving only an arrow labelled 'heat'; it is expected that the method of heating is demonstrated. A common unworkable method was to place a Bunsen burner inside the sealed system; this could not be awarded credit.

The majority of candidates stated a suitable instrument for the measurement of the air pressure. Common responses which did not gain credit included barometers, and various attempts to load a piston with masses and combine this measurement of the area of cross-section of the container, or the use of $P = \rho gh$.

Most candidates gained credit for measuring the temperature. Stronger candidates were often awarded credit on the basis of a diagram showing a labelled thermometer positioned in the salt solution.

Credit was available for the analysis of data. The majority of candidates selected the correct axes for the graph. 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 then needed to explain how the gradient and y-intercept could be used to determine the constants k and q. It was not sufficient to state that the y-intercept = lg $k\sigma$; k needed to be the subject of the equation. Additional detail marks were available for giving the correct logarithmic relationship between θ and P and explaining how the graph would confirm the suggested relationship. Candidates needed to use the words 'relationship is valid if' and the word 'straight' to describe the line.

The additional detail section has a maximum of six marks that could be awarded. 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. It is essential that candidates' answers are relevant to the experiment in the question rather than general 'textbook' rules for working in the laboratory.

Credit was available for a safety precaution. A clearly reasoned precaution relevant to the experiment was required, including a reason why the safety precaution is selected. Good examples were using a safety screen in case of accidents due to the increased pressure and the use of gloves to handle the beaker or flask containing the hot salt solution.

Other creditworthy additional detail included gradually increasing the temperature or pressure, measuring P and θ simultaneously when the salt solution starts to boil, identifying when the salt solution starts to boil and describing a method to ensure that the density of the salt solution remains constant. Candidates should be encouraged to explain improvements to experimental techniques.

Question 2

(a) Candidates who were mathematically confident were able to work through the algebra and achieve credit.

(b) Completing the table was straightforward. Some candidates did not consider the appropriate number of significant figures. The first two readings in the V column were to three significant figures while the last four readings were to two significant figures. The calculated values of the $1/V$ column could be given to three or four significant figures for the first two readings and two or three significant figures for the last four readings. Most candidates found the uncertainties correctly.

(c) (i) The majority of the stronger candidates were awarded full credit. The points and error bars were straightforward to plot. A number of candidates drew large 'blobs' for the plotted points which could not be given credit. Candidates need to take greater care over the accuracy of the error bars and ensure that each error bar is symmetrical.

(ii) The drawing of the straight lines has continued to improve. Candidates who are successful appear to be using a sharp pencil and a transparent 30 cm ruler which covers all of the points. Candidates should ensure that there is a balance of points about the line of best fit. For this particular set of data, the line of best fit should not have passed through the lowest point.

The worst acceptable line was drawn well in general with a noticeable number of strong candidates drawing 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 sufficiently large triangle. A small number of candidates chose points that did not lie on the lines. Candidates should be encouraged to read carefully the quantities from the axes and to pay attention to powers of ten and units. 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.

(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 into $y = mx + c$. Directly reading the value of the intercept from the y-axis of the graph was incorrect as there was a false origin. When determining the y-intercept of the worst acceptable line, candidates need to show clearly the substitution into $y = mx + c$ of a point from the worst acceptable line and the gradient of the worst acceptable line from **(c)(iii)**.

(d) (i) Candidates must clearly show how the gradient and y-intercept were used – credit is not given for substituting data vales from the table into the expression. Nearly all the candidates were able to show the use of the appropriate equation and the gradient to obtain a value for Q. Candidates often did not show sufficient detail in their working to show how a was determined. The final mark required correct powers of ten with appropriate units and an appropriate number of significant figures.

(ii) Showing clear and logical working is essential for this question. Stronger candidates clearly presented their working in a readable, logical order. The majority of the candidates used the method of adding percentage uncertainties of the gradient and y-intercept. A few candidates chose the maximum or minimum method of finding the uncertainty in a and then calculating the percentage error. For this method, candidates needed to choose carefully the values of Q or gradient and y-intercept. Candidates attempting to find the percentage uncertainty by maximum/minimum methods must demonstrate clearly their method.

PHYSICS

Paper 9702/52
Planning, Analysis and Evaluation

Key messages

- Candidates should be encouraged to read the questions carefully before answering them to understand what is required. Planning a few key points before commencing **Question 1** is useful.
- 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. Candidates should take care 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. 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.

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. There were some unworkable setups shown in diagrams. A very large number of candidates did well on the analysis section with clear identification of how the constants could be determined. Many candidates did not provide enough additional detail. 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 and *y*-intercept of a graph. For a number of 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. Some candidates gave the *x*-intercept rather than determining the *y*-intercept.

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

Comments on specific questions

Question 1

The majority of the 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.

Many candidates stated that the temperature of the room needed to be kept constant. Some candidates produced a list of quantities which were either not relevant to the equation or not appropriate. Other candidates stated that *k* and *s* needed to be kept constant. Additional quantities which also gained credit were keeping the surface area of the water constant and keeping the temperature of the water constant while timing the rate of evaporation. A small but significant number of candidates use the incorrect term 'control' rather than the correct term 'constant'.

Credit is available for the method of data collection. 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 how the water could be evaporated and how the temperature of the water could be changed. Closed containers did not gain credit. In addition, candidates needed to label the 'water' on the diagram.

A workable method to find the change in volume was required. Some candidates suggested the use of a measuring cylinder while others suggested the use of a mass balance. Some candidates correctly mentioned to tare the balance. Candidates did not gain credit for suggesting a graduated beaker. Candidates also suggested a stop-watch to record the time for the volume or mass change. Some weaker candidates used a stop-watch to measure the time for the water to be heated rather than the time for the evaporation to occur. Linked with these two marks was an additional detail mark to determine *Y*. Candidates should explicitly state the change in volume. For methods involving the change of mass, candidates needed to demonstrate using the density of the water correctly in the calculation.

Most candidates gained credit for measuring the temperature. Stronger candidates were often awarded credit on the basis of a diagram showing a labelled thermometer positioned in the water.

Credit was available for the analysis of data. The majority of candidates selected the correct axes for the graph. 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 then needed to explain how the gradient and y-intercept could be used to determine the constants *k* and *s*. It was not enough to state that the y-intercept = lg *k*. The subject of the equation needed to be *k*. Additional detail marks were available for giving a correct logarithmic relationship between *Y* and θ and explaining how the graph would confirm the suggested relationship. Candidates needed to use the words 'relationship is valid if' and the word 'straight' to describe the line.

The additional detail section has a maximum of six marks that could be awarded. 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. It is essential that candidates' answers are relevant to the experiment in the question rather than general 'textbook' rules for working in the laboratory.

Credit was available for a safety precaution. A clearly reasoned precaution relevant to the experiment was required, including a reason why the safety precaution is selected. A good example was the use of gloves to handle the beaker containing the hot water.

Other creditworthy additional detail included the method to keep the temperature of the water constant while the rate of evaporation is determined (such as using a water bath or gently heating the water to keep the temperature constant), using a large surface area to increase the rate of evaporation, using insulation around the sides of the beaker to help keep the temperature constant and to switch off fans so as to avoid draughts. Candidates should be encouraged to explain improvements to experimental techniques.

Question 2

(a) Candidates who were mathematically confident were able to work through the algebra and achieve credit.

(b) Completing the table was straightforward. Some candidates did not consider the appropriate number of significant figures. The readings in the I column were to two significant figures. The calculated values of the $1/I$ column could be given to two or three significant figures. Most candidates found the uncertainties correctly, although a small but significant number of candidates incorrectly wrote ±0.5 (the reciprocal of ±2).

(c) (i) The majority of the stronger candidates were awarded full credit. The points and error bars were straightforward to plot. A number of candidates drew large 'blobs' for the plotted points which could not be given credit. Candidates need to take greater care over the accuracy of the error bars and ensure that each error bar is symmetrical.

(ii) The drawing of the straight lines has continued to improve. Candidates who are successful appear to be using a sharp pencil and a transparent 30 cm ruler which covers all of the points. Candidates should ensure that there is a balance of points about the line of best fit. For this particular set of data, the line of best fit should not have passed through the lowest point.

The worst acceptable line was drawn well in general with a noticeable number of strong candidates drawing 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 sufficiently large triangle. A small number of candidates chose points that did not lie on the lines. Candidates should be encouraged to read carefully the quantities from the axes and to pay attention to powers of ten and units. 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.

(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 into $y = mx + c$. Some candidates incorrectly wrote the value of the x-intercept. When determining the y-intercept of the worst acceptable line, candidates need to show clearly the substitution into $y = mx + c$ of a point from the worst acceptable line and the gradient of the worst acceptable line from **(c)(iii)**.

(d) (i) Candidates must clearly show how the gradient and y-intercept were used – credit is not given for substituting data vales from the table into the expression. Nearly all the candidates were able to show the use of the appropriate equation and the gradient to obtain a value for E. Similarly most candidates understood that the value of r was determined by multiplying the value of E by the y-intercept. The final mark required correct powers of ten with appropriate units and an appropriate number of significant figures.

(ii) Showing clear and logical working is essential for this question. Stronger candidates clearly presented their working in a readable, logical order. The majority of the candidates used the method of adding percentage uncertainties of the gradient, y-intercept and R. A few candidates chose the maximum or minimum method of finding uncertainty in r and then calculating the percentage error. For this method, candidates needed to choose carefully the values of E or gradient, y-intercept and R. Candidates attempting to find the percentage uncertainty by maximum/minimum methods must demonstrate clearly their method.

PHYSICS

Paper 9702/53
Planning, Analysis and Evaluation

Key messages

- Candidates should be encouraged to read the questions carefully before answering them to understand what is required. Planning a few key points before commencing **Question 1** is useful.
- 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. Candidates should take care 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. 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.

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. There were some unworkable setups shown in diagrams. A very large number of candidates did well on the analysis section with clear identification of how the constants could be determined. Many candidates did not provide enough additional detail. 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 and *y*-intercept of a graph. For a number of 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. Some candidates did not realise that there was a false origin and so the *y*-intercept could not be read directly from the *y*-axis.

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

Comments on specific questions

Question 1

The majority of the 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. Many candidates stated that the density of the salt solution needed to be kept constant. Some candidates produced a list of quantities which were either not relevant to the equation or not appropriate, e.g. mass of salt, volume of water, initial temperature of solution. A small but significant number of candidates use the incorrect term 'control' rather than the correct term 'constant'.

Additional detail marks were awarded for candidates who stated how the density of the salt solution could be calculated and how it could be determined by making appropriate measurements. Candidates were expected to describe measuring the volume of the salt solution with a measuring cylinder and determining the mass by finding the difference in balance readings – many candidates did not indicate there was a mass difference to be taken. Some candidates correctly mentioned to tare the balance. Credit was not awarded for suggesting a graduated beaker. Candidates should be encouraged to define symbols in any equation that is used.

Credit is available for the method of data collection. 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 how the pressure could be changed. Stronger candidates clearly showed that the system was sealed and attached to a pump. In addition, candidates needed to label the 'salt solution' on the diagram.

A workable method of heating the salt solution was required. The more desirable electrical methods of heating were seen but were much less common than using a Bunsen burner. A sealed flask heated by a labelled Bunsen burner gained credit. Candidates did not gain credit for giving only an arrow labelled 'heat'; it is expected that the method of heating is demonstrated. A common unworkable method was to place a Bunsen burner inside the sealed system; this could not be awarded credit.

The majority of candidates stated a suitable instrument for the measurement of the air pressure. Common responses which did not gain credit included barometers, and various attempts to load a piston with masses and combine this measurement of the area of cross-section of the container, or the use of $P = \rho gh$.

Most candidates gained credit for measuring the temperature. Stronger candidates were often awarded credit on the basis of a diagram showing a labelled thermometer positioned in the salt solution.

Credit was available for the analysis of data. The majority of candidates selected the correct axes for the graph. 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 then needed to explain how the gradient and y-intercept could be used to determine the constants k and q. It was not sufficient to state that the y-intercept = lg $k\sigma$; k needed to be the subject of the equation. Additional detail marks were available for giving the correct logarithmic relationship between θ and P and explaining how the graph would confirm the suggested relationship. Candidates needed to use the words 'relationship is valid if' and the word 'straight' to describe the line.

The additional detail section has a maximum of six marks that could be awarded. 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. It is essential that candidates' answers are relevant to the experiment in the question rather than general 'textbook' rules for working in the laboratory.

Credit was available for a safety precaution. A clearly reasoned precaution relevant to the experiment was required, including a reason why the safety precaution is selected. Good examples were using a safety screen in case of accidents due to the increased pressure and the use of gloves to handle the beaker or flask containing the hot salt solution.

Other creditworthy additional detail included gradually increasing the temperature or pressure, measuring P and θ simultaneously when the salt solution starts to boil, identifying when the salt solution starts to boil and describing a method to ensure that the density of the salt solution remains constant. Candidates should be encouraged to explain improvements to experimental techniques.

Question 2

(a) Candidates who were mathematically confident were able to work through the algebra and achieve credit.

(b) Completing the table was straightforward. Some candidates did not consider the appropriate number of significant figures. The first two readings in the V column were to three significant figures while the last four readings were to two significant figures. The calculated values of the $1/V$ column could be given to three or four significant figures for the first two readings and two or three significant figures for the last four readings. Most candidates found the uncertainties correctly.

(c) (i) The majority of the stronger candidates were awarded full credit. The points and error bars were straightforward to plot. A number of candidates drew large 'blobs' for the plotted points which could not be given credit. Candidates need to take greater care over the accuracy of the error bars and ensure that each error bar is symmetrical.

(ii) The drawing of the straight lines has continued to improve. Candidates who are successful appear to be using a sharp pencil and a transparent 30 cm ruler which covers all of the points. Candidates should ensure that there is a balance of points about the line of best fit. For this particular set of data, the line of best fit should not have passed through the lowest point.

The worst acceptable line was drawn well in general with a noticeable number of strong candidates drawing 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 sufficiently large triangle. A small number of candidates chose points that did not lie on the lines. Candidates should be encouraged to read carefully the quantities from the axes and to pay attention to powers of ten and units. 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.

(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 into $y = mx + c$. Directly reading the value of the intercept from the y-axis of the graph was incorrect as there was a false origin. When determining the y-intercept of the worst acceptable line, candidates need to show clearly the substitution into $y = mx + c$ of a point from the worst acceptable line and the gradient of the worst acceptable line from **(c)(iii)**.

(d) (i) Candidates must clearly show how the gradient and y-intercept were used – credit is not given for substituting data vales from the table into the expression. Nearly all the candidates were able to show the use of the appropriate equation and the gradient to obtain a value for Q. Candidates often did not show sufficient detail in their working to show how a was determined. The final mark required correct powers of ten with appropriate units and an appropriate number of significant figures.

(ii) Showing clear and logical working is essential for this question. Stronger candidates clearly presented their working in a readable, logical order. The majority of the candidates used the method of adding percentage uncertainties of the gradient and y-intercept. A few candidates chose the maximum or minimum method of finding the uncertainty in a and then calculating the percentage error. For this method, candidates needed to choose carefully the values of Q or gradient and y-intercept. Candidates attempting to find the percentage uncertainty by maximum/minimum methods must demonstrate clearly their method.