

PHYSICS

Paper 9702/11
Multiple Choice

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

General comments

Candidates should take particular care to double-check differences between, for example, 60 mm and 60 cm, and between 4.5×10^3 Hz and 450 Hz. An error between, say, 4.6 m s^{-1} and 4.6 km s^{-1} will give an unrealistic value for something like the speed of a cyclist. It should be possible to see from this that an error has been made. Similar mistakes can occur when using a calculator. It is always advisable to put any calculation into a calculator twice; if different answers are found, one of them must be wrong. This only takes a few seconds and it will usually confirm that no mistake has been made in using the calculator.

Candidates found **Questions 6, 20, 21, 22, 24, 32** and **37** difficult. They found **Questions 1, 7, 13, 31** and **38** to be relatively straightforward.

Comments on specific questions

Question 4

A common incorrect answer to this question was **B**. This scale has the right direction but the spacing of the markings is incorrect. At low temperatures, the resistance changes rapidly with temperature so the markings on the ammeter need to be far apart. As the temperature increases, the resistance changes less and the markings need to become closer together.

Question 6

Answers **B** and **D** were commonly chosen by weaker candidates. Both of these show a ball that has a non-zero speed at time $t=0$ which then decreases as t increases, so these cannot represent the motion of a ball falling freely in air.

Question 20

Many weaker candidates chose **C** and **D**. The horizontal axis of the graph is time so XY cannot be the wavelength.

Question 21

This question required recall of the electromagnetic spectrum. Weaker candidates often chose **C**. If candidates are more familiar with wavelengths, they could have calculated the wavelength ($30\ \mu\text{m}$) and it may then have been clearer that the wave must be infra-red.

Question 22

Just before point **B** the particle is moving away from the source (towards **B**), and just after point **B** it is moving towards the source (also towards **B**), so **B** must be the centre of a compression. Point **D** is the centre of a rarefaction. The other two points are midway between centres of compression and rarefaction.

Question 24

When the rate of rotation increases, the speed of the star increases both as it approaches and as it recedes. This must increase the maximum observed frequency and reduce the minimum observed frequency.

Question 26

Candidates needed to read this question carefully. There is a path difference of 8 cm (4 wavelengths) between S_1P and S_2P , and this led many candidates to think that constructive interference takes place at point P. However, there is a phase difference of 180° between the oscillations of the two sources, so the interference is destructive at P.

Question 32

To get the correct answer, candidates needed to realise that if the length is doubled and the volume is constant, then the area of cross-section must be halved. Using the expression $\rho L/A$ for resistivity then gives the answer as **D**.

Question 37

Each wire has a resistance of $4.0\ \Omega$. There is a current of $0.6\ \text{A}$ and therefore a potential difference across each wire of $2.4\ \text{V}$. The required output p.d. must be $16.0 + 2 \times 2.4 = 20.8\ \text{V}$. Candidates choosing **C** had not considered that there are two wires.

PHYSICS

Paper 9702/12
Multiple Choice

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

General comments

Candidates should take particular care to double-check differences between, for example, 60 mm and 60 cm, and between 4.5×10^3 Hz and 450 Hz. An error between, say, 4.6 m s^{-1} and 4.6 km s^{-1} will give an unrealistic value for something like the speed of a cyclist. It should be possible to see from this that an error has been made. Similar mistakes can occur when using a calculator. It is always advisable to put any calculation into a calculator twice; if different answers are found, one of them must be wrong. This only takes a few seconds and it will usually confirm that no mistake has been made in using the calculator.

Candidates found **Questions 6, 7, 13, 28 and 33** difficult. They found **Questions 2, 3, 22, 23, 31 and 37** to be relatively straightforward.

Comments on specific questions

Question 1

Many weaker candidates chose **D**. These candidates used the radius of the atom rather than its diameter when finding the number of layers.

Question 6

Candidates choosing either **B** or **D** had neglected the horizontal motion of the particle. The speed is never zero because there is a constant component of velocity in the horizontal direction, so neither of these graphs can represent the speed.

Question 7

Many candidates chose **A**. This cannot be correct because the non-zero gradient at time $t = 0$ shows a non-zero velocity. Only graph **C** has a zero velocity at time $t = 0$.

Question 11

Many candidates chose **A** or **B**, but the Moon has no atmosphere so the horizontal force must be zero.

Question 13

Candidates found this question difficult. As the person moves towards the rods, the moment of the person's weight at both P and Q decreases, and therefore the forces exerted by the rods at both P and Q must also decrease.

Question 24

Candidates should be encouraged to sketch graphs to help with answering this type of question.

Question 28

The vibrations at points X and Y are in phase. The pattern of movement at Y will therefore be the same as at X, but the maximum amplitude will be lower because X is at an antinode and Y is not, so **A** must be correct. The three incorrect answers were chosen by candidates with similar frequency.

Question 33

Candidates needed to look at the axes carefully. Many candidates chose **A**, perhaps thinking that the graph had been plotted with voltage on the horizontal axis.

Question 37

Stronger candidates did not find this question difficult, but many weaker candidates did. A common answer from weaker candidates was **A**. Candidates may find this type of question easier to answer in stages. If the current is the same in the thermistor and resistor, then V/R must be the same for these two components. Therefore $7.5/R_T = 4.5/150$ and this gives $R_T = 250\ \Omega$, which is **C**. This structured approach may be less prone to mistakes than trying to remember more complex equations for potential dividers.

PHYSICS

Paper 9702/13
Multiple Choice

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

General comments

Candidates should take particular care to double-check differences between, for example, 60 mm and 60 cm, and between 4.5×10^3 Hz and 450 Hz. An error between, say, 4.6 m s^{-1} and 4.6 km s^{-1} will give an unrealistic value for something like the speed of a cyclist. It should be possible to see from this that an error has been made. Similar mistakes can occur when using a calculator. It is always advisable to put any calculation into a calculator twice; if different answers are found, one of them must be wrong. This only takes a few seconds and it will usually confirm that no mistake has been made in using the calculator.

Candidates found **Questions 14, 16, 18, 30 and 38** difficult. They found **Questions 6, 12, 23 and 34** to be relatively straightforward.

Comments on specific questions

Question 10

For candidates who understand upthrust, this question is very straightforward. The upthrust depends on the pressure difference between the top and the bottom of the cuboid. It cannot depend on what is inside the cuboid, so the correct answer must be **A**.

Question 14

Candidates found this question difficult. The pressure inside the cylinder varies in a way that cannot be determined from the information given, and the frictional force acting on the piston is also unknown. We do know that atmospheric pressure is constant and the work done against the atmosphere must be given by $(p\Delta V =) \text{atmospheric pressure} \times Ar$.

Question 16

It is important to read this type of question carefully. It is relatively straightforward to see that **A** and **C** cannot be the answer. Some candidates chose **D**, but this cannot be the answer because some work is done against air resistance as the ball moves through the air.

Question 18

This question required care to be taken, both with powers of ten and with the distinction between radius and diameter.

Question 24

A loud sound is heard when there is a node at the surface of the water and an antinode at the top of the cylinder. Between two of these loud sounds, the water level must have changed by half a wavelength so that there is one more node in the stationary wave pattern. This gives $(67.3 - 2.9) = 64.4 \text{ cm} = \frac{1}{2}\lambda$. The frequency is then $f = 330/\lambda (= 256 \text{ Hz})$.

Question 30

This question required care with powers of ten. Stronger candidates did not find it difficult but many weaker candidates chose **B** or **C**.

Question 35

Answers **B** and **D** were both common. Candidates needed to take a logical approach: first, they needed to use the information given to find the resistance R of the unknown resistor: $1/2.5 = 1/5.0 + 1/(2R)$. This gives $R = 2.5\Omega$. The value can then be used to find the resistance between X and Y.

Question 38

Answers **B** and **C** were both common. The resistances of the resistors must be in the same proportion as the lengths of the resistance wire, so $V_1/V_2 = x/(L - x)$.

PHYSICS

Paper 9702/21 AS Level Structured Questions
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Key messages

- Candidates should be encouraged to recall definitions in precise detail. The omission of a key word may prevent credit from being awarded.
- The command words used in a question should be carefully considered. A glossary of command words is provided in the syllabus. When candidates are asked to 'state and explain', it is essential that an explanation is included in the answer as well as a final statement.
- Candidates should be made aware that prematurely 'rounding off' any intermediate answers in the middle of a numerical calculation can lead to an inaccurate final answer.
- In numerical calculations it is important that candidates always explicitly state the subject of any equations. If an equation is rearranged, the new subject should also be stated.

General comments

A single word can make a difference to a definition or an explanation. For example in **Question 2(a)** candidates used a variety of words/phrases such as force, external force, balanced force and resultant force. Only resultant force is acceptable as part of the answer in **Question 2(a)**. In **Question 3(b)(iv)** '...different relative speeds...' is correct, whilst '...different speeds...' is not. In **Question 4(a)(ii)** 'distance between two consecutive peaks' is acceptable, whilst 'distance between two peaks' is not. In **Question 5(a)(ii)** 'waves with a constant phase difference' is correct, whilst 'waves with the same phase difference' is not. All these examples were seen frequently, showing that some candidates would benefit from providing greater precision in their answers.

In **Question 6**, many candidates found it difficult to apply their understanding of basic circuitry to the resistances in series and parallel. In **Question 7(c)**, many candidates were not able to explain the variation in path taken by beta particles in an electric field due to the particles having a range of velocities when emitted from a nucleus.

Candidates should be encouraged to read questions carefully to ensure their answers are appropriate in context, rather than simply repeating memorised extracts.

There was no evidence that 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 acceptable explanations of scalar and vector quantities.
- (b) The majority of the candidates were able to answer correctly for at least two of the quantities listed. There were many who incorrectly considered power to be a vector and a few gave temperature as a vector.
- (c) (i) A large proportion of the candidates drew a vector for the resultant velocity in a direction that suggested they had given insufficient thought as to how the aircraft velocity and the wind velocity



would combine. In this case the aircraft velocity was the major factor when considering the effect of the wind on the resultant direction of the aircraft.

- (ii) Candidates found this question difficult. Many candidates assumed that the angle between the wind velocity and the aircraft was 90° and used Pythagoras' theorem. A considerable number used the cosine rule with the included angle being 65° . There were many incorrect vector diagrams. A significant number resolved the wind velocity into a north direction only.

A small number of candidates used a scale diagram, usually with some success. A significant number obtained the correct answer either by using the cosine rule with the included angle being 115° or by resolving the wind velocity into two components parallel (to the west) and perpendicular (to the north) to the aircraft velocity, and then using Pythagoras' theorem to determine the resultant.

Question 2

- (a) The wording given by many candidates was too imprecise. Instead of including constant velocity and resultant force, common answers included uniform motion and just force, balanced forces or an external force. When using speed instead of velocity candidates tended to omit 'in a straight line'.

- (b)(i) 1. The majority of the candidates attempted to calculate the area under the line of the velocity-time graph. Many did not apply the vector nature of velocity and displacement and so added, rather than subtracted, the two areas and then gave the direction as upwards.

A significant number misread the velocity from the graph. At time $t = 0$, instead of -6.8 ms^{-1} , either -7.0 ms^{-1} or -7.2 ms^{-1} was used, and at $t = 3.0 \text{ s}$, instead of 3.4 ms^{-1} , 3.2 ms^{-1} was used.

2. This question was generally well answered. The majority of the candidates used the expression for the gravitational potential energy and their answer to (b)(i) part 1, and many candidates were awarded full credit.

- (ii) The acceleration was determined correctly by the majority of candidates. Many determined the gradient of the graph. Others attempted to use more complicated equations of constant acceleration, but sometimes made errors with the signs of the velocities used. There were some who used too small a triangle for the gradient and this led to inaccuracy in the value of the acceleration.

- (iii) The stronger candidates were usually awarded full credit. The weaker candidates were unable to progress from the equation $F = ma$ or left this part blank. The difference between the tension and the weight gives the resultant force. Some candidates did not realise that the resultant force and the acceleration are in the same direction and gave $15 - T = 1.53 \times 3.4$. A number of candidates began with an incorrect expression and then manipulated the mathematics to arrive at an answer of 20 N, but this approach could not be awarded credit.

- (iv) There were many correct answers. Common errors were due to using the weight and not the tension when calculating the stress, or not rearranging a correct expression for the Young modulus to be in terms of the strain.

- (v) The majority of candidates found this part challenging and there were very few complete answers. Some thought that, because the question referred to the block moving vertically, they had to explain what happens to the horizontal motion of the block. Few mentioned that the block was in equilibrium or that the resultant force was zero, and a smaller number realised that this meant the block could either be stationary or moving with constant velocity.

Question 3

- (a) The majority of candidates correctly referred to the quantity of matter. Some candidates used incorrect terms such as amount of substance or the number of molecules. A significant number described mass in terms of weight and gravitational field strength, whilst others expressed it in terms of density and volume. These expressions are used to define gravitational field strength and density respectively and are not appropriate here.

- (b)(i) Many answers did not contain enough detail to gain full credit. For example, candidates often did not make it clear that the force *on A* is equal and opposite to the force *on B* or that force is the *rate of change of momentum*. Weaker candidates referred to 'action and reaction' and related these terms directly to momentum. This is not acceptable for Newton's third law at this level.
- (ii) This question was generally well answered. A common error was to give the wrong sign for the momentum of block B before the collision. The relationship between the total momentum before the collision and the total momentum after the collision was known by the majority of candidates.
- (iii) Common errors were to subtract the values for the speed of approach and to add the values for the speed of separation.
- (iv) Many candidates explained their answer in terms of kinetic energy without reference to relative speeds. Some candidates referred to there being a difference in the total momentum which shows a misunderstanding of the physics of collisions.

Question 4

- (a)(i) The majority of candidates gave a correct answer in terms of oscillations or cycles. The time for a wave or a wavelength was a common answer that was considered too vague to warrant credit.
- (ii) There were many answers that were given with insufficient detail. Some candidates wrote that the wavelength is the length of a wave. Many candidates wrote in terms of the distance between two crests, troughs or points oscillating in phase, but neglected to state that these must be adjacent. Some suggested that wavelength was the shortest distance between 'similar' points without explaining what was meant by 'similar'.
- (b)(i) The majority of candidates obtained the correct answer. Some made an error in rearranging the expression for the wavelength in terms of the time period and the speed of the wave. A significant number obtained the wrong value for the time period from the graph, with 0.30 s and 0.80 s being common incorrect answers.
- (ii) Only the strongest candidates were able to determine the phase difference.
- (iii) Most candidates obtained full credit. A few candidates gave an answer to only one significant figure. A small minority did not know the correct relationship between intensity and amplitude.
- (iv) A significant number of candidates gave the correct answer. Some gave incorrect answers by not taking into consideration the vector nature of displacement. The two displacements at 0.45 s were often added or the final sign for the displacement omitted. A further common error was to misread the time axis for 0.45 s and give the difference in displacement as -2.6 mm (the difference at 0.50 s).

Question 5

- (a)(i) Many answers would have benefited from greater detail. The majority of candidates described the waves as spreading or said that the waves needed to pass through a slit, although very few said both. There were some answers that described refraction with the waves bending.
- (ii) Some candidates gave the correct explanation. There were many incorrect answers that gave descriptions of waves with the same phase or same phase difference. Other answers that were not accepted described waves that had the same wavelength, the same frequency or the same amplitude.
- (b)(i) Most candidates could give the correct diffraction grating formula. The algebra that followed to show the ratio of the wavelengths was often incorrect or not shown in sufficient detail. One of the important aspects of a 'show that' question is that candidates are expected to show all the relevant steps of the calculation. There were many candidates who missed out key points such as labelling which n or which λ they were using in subsequent expressions. Another common error was to assign 90° to θ and make $\sin \theta = 1$.

- (ii) This was a difficult question. The strongest candidates were able to obtain the correct answer. A significant proportion did not give any response.

Question 6

- (a) There were very few candidates who gave the correct answer. Many gave a definition of potential difference or stated 'current $\times$ resistance' or 'ampere $\times$ ohm'.
- (b)(i) The correct current was determined by a significant number of candidates. Only a small number explained their working by stating that the potential difference (p.d.) across each lamp was the same because the lamps were connected in parallel. Some candidates ignored the value given for the current in lamp P and determined the currents through each lamp at a p.d. of 4.0 V. Others added the current at 4.0 V for lamp Q to that given for lamp P at 2.7 V.
- (ii) Many candidates incorrectly used the e.m.f. of 4.5 V for the p.d. across resistor R.
- (iii) The majority of the candidates could give the relevant symbol formula for resistivity. A smaller number calculated the resistance of each lamp. Many candidates assumed that the resistance of each lamp was the same and determined a ratio that depended only on the areas of the wires used for the lamps.
- (iv) Candidates found it difficult to explain the changes in the circuit due to the filament wire of lamp Q breaking. The majority of candidates assumed that the p.d. across P would not change and stated that the resistance and current were inversely related. Only a very small number stated that the increase in current in P would cause the resistance of P to increase. A smaller number stated that the p.d. across P would increase.

Question 7

- (a) The majority of candidates drew an arrow in the vertical direction, although many drew it in the wrong direction. Others drew arrows that were horizontal or along the path of the particle. A few candidates drew symbols representing magnetic fields.
- (b) Most candidates were able to link the energy in eV to the symbol formula for kinetic energy. The majority of answers were fully correct. Some did not convert the energy given in eV into joule.
- (c) A small minority of candidates described a range of paths for the beta particles due to their having a range of kinetic energies. Many candidates misinterpreted this question: having read 'outside the electric field' in the first sentence they then did not register the phrase 'inside the electric field' in the second sentence and framed their answer in terms of particles not experiencing an electric force. Another common error was to state that all beta particles have the same mass and charge and so follow the same path, without realising that the particles have a range of speeds.

PHYSICS

Paper 9702/22 AS Level Structured Questions
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Key messages

- Candidates should be encouraged to recall definitions in precise detail. The omission of a key word may prevent credit from being awarded.
- The command words used in a question should be carefully considered. A glossary of command words is provided in the syllabus. When candidates are asked to 'state and explain', it is essential that an explanation is included in the answer as well as a final statement.
- Candidates should be made aware that prematurely 'rounding off' any intermediate answers in the middle of a numerical calculation can lead to an inaccurate final answer.
- In numerical calculations it is important that candidates always explicitly state the subject of any equations. If an equation is rearranged, the new subject should also be stated.

General comments

In general, candidates would benefit from improving their understanding of the Doppler effect, stationary waves in air columns and solving d.c. circuit problems. They found **Questions 3(e), 4(b) and 6(b)** challenging.

The candidates did not have any difficulty understanding the language used in the questions and there was no evidence of candidates lacking time to complete the question paper.

Comments on specific questions

Question 1

- (a) The most common incorrect definition of force was 'the product of mass and acceleration'. Other incorrect definitions included 'a push or a pull' and 'the rate of change of momentum per unit time'.
- (b) This part of the question was very well answered. The most common incorrect response was 'newton'.
- (c) A significant number of answers incorrectly stated the base units of charge as either C or As^{-1} . Care needed to be taken when combining the indices of the base units. A common error in the working was to cancel s^2 in the numerator with s^{-2} in the denominator.

Question 2

- (a) The majority of the candidates were awarded full credit. It is important that candidates explicitly refer to total momentum remaining constant when there is no external resultant force. Some weak candidates confused the terms moment and momentum.
- (b)(i) Different methods of calculation were possible. Almost all the candidates chose the most straightforward method, which was to consider conservation of momentum in the direction perpendicular to line AB. This method of calculation was usually done successfully, although some candidates calculated components parallel to line AB when they should have been finding

components perpendicular to line AB. A few candidates chose to do the calculation using the cosine rule.

- (ii) The majority of answers were correct. A small proportion of the candidates stated the correct symbol formula for the kinetic energy of an object, but then forgot to square the speed when substituting the numerical values into the formula.

Question 3

- (a) Most answers were correct.
- (b) The distance moved up the slope and the distance moved down the slope were usually calculated correctly. A common error was to add, rather than subtract, these two distances. Candidates who made this error seemed to have overlooked that the question asks for the displacement of the sledge, not the total distance travelled by the sledge.

A small proportion of the candidates incorrectly assumed that the acceleration of the sledge remained constant over the entire range of time and so attempted to calculate the displacement in one step using a single equation of uniform acceleration.
- (c) The majority of the answers were correct. Most candidates chose to calculate the acceleration from the gradient of the graph. Candidates who chose to use an equation of uniform acceleration needed to be careful with the signs of any numerical values substituted into the equation.
- (d)(i) The resultant force acting on the sledge was usually calculated correctly, although a very small number of candidates used an incorrect acceleration of 9.81 m s^{-2} instead of the correct acceleration of 0.50 m s^{-2} . The value of the resultant force was then usually subtracted from the component of the weight down the slope, although some candidates made the mistake of adding these two forces.
- (ii) Most candidates understood how to calculate the angle of the slope. The most common errors were either using the wrong trigonometric function in the calculation or substituting an acceleration of free fall of 10 m s^{-2} instead of 9.81 m s^{-2} .
- (e)(i) Most candidates realised that they needed to use the Doppler effect equation listed in the Formulae sheet. Many candidates found it difficult to apply the equation. Common errors included substituting the speed of the sledge with the wrong sign or reading the wrong magnitude of speed from the graph. A significant number of answers confused the observed frequency with the source frequency.
- (ii) Only the strongest candidates realised that the man would hear an increasing frequency because the sledge is moving away from him with a decreasing speed. Many did not take into account the deceleration of the sledge and incorrectly believed that the man must hear a decreasing frequency simply because the sledge is moving away from him.

Question 4

- (a)(i) The most common correct definitions were 'the distance between two consecutive crests/troughs' and 'the minimum distance between two crests/troughs'. When choosing to define wavelength this way, it is important to include either the word 'consecutive' or the word 'minimum'. Some candidates said that it was the minimum distance between two similar points, but did not explain what was meant by 'similar'. The weakest candidates sometimes incorrectly defined wavelength as wave speed divided by wave frequency.
- (ii) An antinode is a position where the stationary wave has maximum amplitude. Candidates should be encouraged to describe nodes/antinodes in terms of amplitude rather than displacement.
- (b)(i) Most answers gave the correct symbol equation that relates speed, frequency and wavelength. Many candidates did not understand the wave profile of the stationary wave in the air column and so tended to substitute an incorrect value of wavelength, such as 4.5 cm or 9.0 cm, into the equation.

- (ii) A significant number of candidates did not attempt this question. Others did not realise that the distance moved by the piston is equal to half of a wavelength. Very weak candidates sometimes confused the speed of the piston with the speed of sound, or stated the period of the wave as the final answer.

Question 5

- (a) The majority of answers were fully correct.
- (b) In 'show that' questions, credit is given for showing the working as well as the final answer. Candidates need to carefully present all the steps of their calculation. Two methods of calculation were seen. The most common method was to calculate the pressure due to the oil on the bottom face of the cylinder and then to multiply this pressure by the area of the face. The other method was to equate the upthrust to the weight of the oil that is displaced by the cylinder.
- (c) (i) This question was often well answered. A minority of the candidates either did not take into account the upthrust on the cylinder or incorrectly added the upthrust to the cylinder's weight.
- (ii) The relevant symbol equation was generally well known and usually applied correctly.
- (d) (i) Many candidates of average ability were able to explain that the upthrust on the cylinder decreases as the cylinder is raised. The stronger candidates then went on to explain successfully that the tension or lifting force from the motor increases so the power output of the motor also increases. Common misconceptions held by weaker candidates were that the resultant force on the cylinder increases or that the weight of the cylinder increases.
- (ii) Candidates found this question difficult. Incorrect reasons included the inefficiency of the motor and the viscous force due to the oil.

Question 6

- (a) (i) Candidates needed to refer to the sum of the currents entering a junction being equal to the sum of the currents leaving the junction. No credit was given for statements that omitted 'sum'. Very weak candidates sometimes confused Kirchhoff's first and second laws.
- (ii) There were many incorrect quantities stated, such as energy and voltage.
- (b) (i) 1. The symbol formula for power was usually stated correctly. However, the numerical values substituted into the formula were often incorrect. Many candidates did not appreciate the difference between the terminal potential difference, the electromotive force, and the potential difference 'lost' across the internal resistance of a battery.
2. Many candidates found it straightforward to calculate the terminal potential difference. The most common incorrect answer was 5.0 V, which is the potential difference 'lost' across the internal resistance of the battery.
- (ii) Different methods of calculation were possible. The most common method was to first find the combined resistance of the two external resistors that are connected in parallel. The combined resistance could then be used to find the resistance of wire Y. Common errors included either ignoring the internal resistance of the battery or treating the internal resistance as being in parallel with the two external resistors.
- (iii) 1. Most candidates realised that the new wire could have a larger cross-sectional area or be made of material of lower resistivity. A significant number incorrectly referred to the new wire having a shorter length, even though the question stated that the length remained unchanged. Very weak candidates sometimes confused the terms resistance and resistivity.
2. This question was reasonably well answered. A significant minority of candidates did not consider the current in the battery, even though the question stem referred to current. A small number of candidates realised that the current in the battery would increase, but then incorrectly stated that the total power produced by the battery would decrease because more power is dissipated by the internal resistance. Those candidates seemed to be confusing the total power produced by the battery with the useful output power that it produces.

Question 7

- (a) Most candidates were able to correctly identify the two leptons in the nuclear equation. A significant minority either did not know that an antineutrino is a lepton or made no attempt to answer the question.
- (b) The name of the particle was correctly stated in the majority of answers. Some candidates need to learn the precise spelling of antineutrino so that it cannot be confused with other similar words.
- (c) Some candidates stated incorrect forms of energy, such as 'gamma energy' and 'nuclear energy'.
- (d) Many candidates wrongly stated that the two nuclei were isotopes and gave various incorrect reasons for this. Common mistakes included thinking that the two nuclei had the same number of neutrons or thinking that nucleus X was a single neutron. Some candidates gave a general definition for isotopes, but did not apply their definition to the question.
- (e) Stronger candidates found this question to be straightforward. A small minority described the change to the quark composition in the reverse direction. Others stated the final quark composition, but not the change to the composition.

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Paper 9702/23 AS Level Structured Questions
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Key messages

- Candidates should be encouraged to recall definitions in precise detail. The omission of a key word may prevent credit from being awarded.
- The command words used in a question should be carefully considered. A glossary of command words is provided in the syllabus. When candidates are asked to 'state and explain', it is essential that an explanation is included in the answer as well as a final statement.
- Candidates should be made aware that prematurely 'rounding off' any intermediate answers in the middle of a numerical calculation can lead to an inaccurate final answer.
- In numerical calculations it is important that candidates always explicitly state the subject of any equations. If an equation is rearranged, the new subject should also be stated.

General comments

The performance of the candidates taking this paper varied considerably. There were many candidates who were able to successfully apply their knowledge and understanding to the unfamiliar situations posed by the questions. Conversely, there were a significant number of weaker candidates who needed to improve their fundamental knowledge in order to be able to answer questions at this level.

Most candidates had a good understanding of how to apply the equations of uniform acceleration in **Questions 3(a)** and **3(b)**. A significant number found it difficult to determine the strain energy in a deformed sample of a material from a graph of length against force in **Question 4(b)(ii)**. Many candidates also found it difficult to apply their understanding of how waves interfere to **Questions 5(b)(ii)** and **5(b)(iii)**.

Comments on specific questions

Question 1

- (a) (i) The majority of the candidates were able to give an appropriate example of a systematic error. Usually this was the voltmeter having a zero error, but a significant number of candidates also referred to the voltmeter having an incorrectly calibrated scale.
- (ii) Many answers were too vague, such as 'not recording the right reading' or 'human error'. The most common correct answer was reading the scale from different angles.
- (b) (i) The power dissipated by the resistor was usually calculated correctly.
- (ii) Most candidates found it straightforward to calculate the percentage uncertainty in the power from the percentage uncertainties of the potential difference and the resistance. A common error was to forget to double the percentage error in the potential difference.
- (iii) The value of the absolute uncertainty was usually calculated correctly. However, some candidates wrote down the final answer with an inappropriate number of significant figures.

Question 2

- (a) Work done was often stated as being ‘the product of a force and displacement’. This statement is incomplete because it does not make it clear that the displacement is in the direction of the force (a moment is also a product of a force and a displacement).
- (b) (i) The calculation of the density of the material of the sphere was generally well done, although a small number of candidates were unable to recall the formula for the volume of a sphere.
- (ii) A small number of candidates appreciated that the origin of the upthrust acting on the sphere is that the pressure on its lower surface is greater than the pressure on its upper surface. A common misconception is that the upthrust is caused by the density of the water being greater than the density of the sphere.
- (iii) The majority of answers correctly used the resultant force on the sphere to calculate its acceleration. A minority did not take into account the weight of the sphere and so incorrectly assumed that the resultant force was equal to the upthrust.
- (iv) Most candidates knew that the sphere only moves with a constant speed when the resultant force acting on it is zero. This knowledge enables the drag force and hence the speed of the sphere to be calculated. The most common mistake was to ignore the weight of the sphere and so wrongly assume that the drag force was equal to the upthrust.
- (v) Most candidates attempted to use the Doppler effect equation stated on the Formulae sheet. This equation was usually applied correctly to the question. Although the question asked candidates to determine the final answer to three significant figures, some candidates incorrectly stated it to either two or four significant figures.

Question 3

- (a) The appropriate equation of uniform acceleration was usually applied correctly.
- (b) The majority of the candidates correctly used an appropriate equation of uniform acceleration. A small number of candidates chose to calculate the height of the ceiling by equating the decrease in kinetic energy of the ball to its increase in gravitational potential energy.
- (c) (i) The equation for the change in the gravitational potential energy of an object was usually recalled and applied correctly.
- (ii) Most of the candidates were able to recall the symbol formula for the kinetic energy of an object. The decrease in the kinetic energy of the ball from the time it was thrown was sometimes calculated instead of the required decrease in kinetic energy from the time that the ball first makes contact with the ceiling.
- (d) Candidates needed to state in precise terms how Newton’s third law applied to the collision between the ball and the ceiling. A general statement of the law was, on its own, insufficient.
- (e) The formula for the momentum of an object was correctly recalled by almost all of the candidates. Many candidates confused the momentum of the ball when it first makes contact with the ceiling with the momentum when it was first thrown.
- (f) Most candidates appreciated that the average resultant force on the ball during the collision was equal to its change of momentum per unit time. However, the calculation of the average resultant force often used the time taken for the ball to travel to the ceiling (0.37 s) instead of the time taken during the collision with the ceiling (0.085 s). Another common error was to assume that the average resultant force on the ball during the collision was the same as the average force exerted on the ball by the ceiling.

Question 4

- (a) The Young modulus of a material was usually defined correctly. No credit could be given for just a symbol equation without explaining the meaning of the symbols.

- (b)(i) This question was generally well answered. A common error was to assume that the spring constant was equal to the gradient of the given graph instead of the reciprocal of the gradient. Weaker candidates sometimes confused the length of the rod with its extension.
- (ii) The majority of the candidates were able to state a general symbol equation for strain energy. The application of the equation to the graph was more difficult. A common error was to confuse the length of the rod with its extension. Weaker candidates often stated that the strain energy was represented by the area of the graph, but did not understand which area of the graph to calculate. Very weak candidates sometimes confused the terms strain energy and strain.
- (c) Most candidates deduced that the new graph line would be below the original line, but only a small proportion were able to draw the new line with the correct gradient. Some candidates ignored the instruction to draw the new line on the original graph grid and instead tried to construct a whole new graph in the blank area of the page. This wasted valuable time and made it more difficult to gain full credit.

Question 5

- (a) This question was generally well answered. A significant minority of candidates incorrectly stated that intensity is equal to the square of amplitude instead of the correct relationship which is that intensity is directly proportional to the square of amplitude.
- (b)(i) This was a straightforward calculation for most candidates. The most common errors were not converting the units of the wavelength from centimetres to metres and substituting the speed of sound instead of the speed of the microwaves.
- (ii) A significant proportion of the candidates did not attempt this question. The key to answering it was to determine that the path difference of the waves at X is exactly equal to three wavelengths. Therefore the waves must have zero phase difference at X and produce an intensity maximum. Many candidates were unable to apply their knowledge of interference and made vague comments such as 'the phase difference at X is constant'. In general, most candidates would benefit from having a greater understanding of experiments that demonstrate two-source interference.
- (iii) 1. The effect of the decrease in wavelength was not well understood. Many candidates appeared to guess what the effect would be.
2. Many candidates wrongly thought that changing the phase difference between the waves emitted from the sources to 180° would result in there being no detectable interference pattern anywhere along the path of the detector. Others commented only on the effect at point X rather than the effect along the detector's path. A small minority confused microwaves with visible light and inappropriately made reference to bright and dark fringes.

Question 6

- (a) Most candidates were able to state the relevant symbol equation. Although there were many fully correct answers, some were spoilt by careless mistakes such as confusing the wire's diameter with its radius and not converting the units of the diameter from millimetres to metres.
- (b)(i) Many candidates did not understand the effect of the battery's internal resistance on the terminal potential difference. Some ignored the internal resistance altogether and assumed that the potential difference across resistor R was equal to the e.m.f. of the battery (5.0 V).
- (ii) 1. Different methods of calculation were possible. The most common method was to first find the combined resistance of the two external resistances that are connected in parallel. The combined resistance could then be used to find the resistance of wire X.
2. This question was generally well answered by the majority of candidates, although a significant number made no attempt at an answer.

Question 7

- (a) (i) Most candidates understood that the emission of an α -particle from a nucleus will cause the proton number to decrease by two and the nucleon number to decrease by four. Some candidates wrongly thought that the nucleon number represented the number of neutrons in a nucleus.
- (ii) The cross representing nucleus R was usually plotted correctly. A common error was to assume that the emission of a β^- particle from a nucleus will cause the proton number to decrease by one.
- (b) The majority of the candidates correctly identified the class (group) of particles as being leptons. A small minority thought it was hadrons.
- (c) A significant proportion of candidates did not attempt this question. The most common incorrect answer was that an up quark was changed to a down quark.

PHYSICS

Paper 9702/31 Advanced Practical Skills 1
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Key messages

- Candidates are encouraged to record all their raw data (in the table and elsewhere), show this clearly and not just state the final mean value.
- 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. They could also draw lines of best fit for data on graph paper and then use a computer to draw the line of best fit, and compare the two. 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. It was clear that most Centres work hard to provide the equipment specified in the Confidential Instructions. Centres were requested to provide stands, bosses and clamps. It would be helpful if Centres could ensure all stands, bosses and clamps are tightened up so they grip well and do not wobble. A stated common source of difficulty was loose clamps or clamps which did not grip well.

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 normally attempted and there did not seem to be a shortage of time in most cases. Weaker answers showed that determining a periodic time was difficult. 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 d which was in the appropriate range, to the nearest mm and with a correct unit. Good answers had a value of s in the range $30\text{ cm} \pm 1\text{ cm}$. Weaker candidates often had values of s above 31 cm.

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 rule correctly arranged, successful candidates correctly stated a value for the period T which was in the appropriate range and had the correct unit of seconds. To find the period accurately, several consecutive oscillations e.g. 10 needed to be measured at least twice, and the time for one oscillation was calculated as (total time for 10 oscillations)/10. Successful candidates showed the equation had been remembered.

Weaker answers had the total time on the answer line, inadvertently found frequency using an inverted equation or showed that the stop-watch had been misread. It was common for weaker candidates to measure the period by timing single oscillations.

- (c) Successful candidates gave new values for s and T following adjustment of the apparatus.

- (d) Strong candidates recorded five sets of readings and included raw values of time, along with periodic times T and the distance s in neatly presented tables, and the table values showed the correct trend. A number of tables in weaker answers showed confusion between period and frequency resulting in an incorrect trend in the data.

Better answers included a large variation in s values i.e. the largest s value and the smallest s value that could be achieved with the apparatus. These candidates varied s from less than 70 cm to 85 cm or more. Weaker answers showed a variation in s of only a few centimetres.

Strong candidates included a correct quantity and unit in every column heading. These answers included a separating mark, such as a solidus, between the quantity and unit e.g. s/cm , t_1/s , t_2/s , T/s and T^2/s^2 . Weaker answers omitted units or did not include a separating mark between the quantity and its unit e.g. $T^2\text{ s}^2$.

Candidates should be encouraged to record raw values of the time for n oscillations in their tables, and not just the values of calculated period.

Consistent answers reflected the precision of the stop-watch, so all readings of raw time were given to 0.1 s or 0.01 s.

Successful treatment of significant figures was shown when calculated values for T^2 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 time values.

Many candidates calculated T^2 correctly. Weaker answers had errors in calculations often caused by incorrect rounding of the final value by truncating rather than rounding.

- (e) (i) Stronger candidates used axes for their graphs that were labelled with the appropriate quantities e.g. T^2 or s . 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 0.6 or 0.34. 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, 0.1, 0.2, 0.25, 0.4 or 0.5. Weaker answers used, for example, 10 small squares equal to 12 as then one small square with this scale was worth 1.2.

Some candidates used scales with values missing, e.g. 1.8, 2.0, 2.4 (where 2.2 is missing). Some also had scales where the last value was 'squashed' to fit by changing the scale e.g. 1.6, 1.8, 2.0, 2.4.

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.

- (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 $s = 0$ 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 $s = 0$, giving a false origin.

- (f) Candidates needed to make a direct transfer of values from (e)(iii) to (f). P was equal to the value of the gradient and Q was equal to the value of the intercept, and no additional calculations were necessary. Weaker answers recorded fractions for P or Q or showed fresh substitutions into the equation and further calculations.

Some candidates did not include the units or gave wrong units.

Question 2

- (a) Most candidates carefully adjusted the position of the magnet to produce a value of x close to 3 mm. Good answers had measured values of the small distance x , stating the length with its unit e.g. 0.4 cm. Weaker answers had a value of 3 cm. Measuring the small distance x with a metre rule was difficult and this could be stated as a source of limitation in (g).
- (b) Successful candidates recognised that this measurement was difficult and noted down repeat readings showing the experiment had been done more than once. Again this measurement could be used as a source of limitation in (g). The measurements of y required a unit and successful answers noted readings to the nearest mm e.g. 8.5 cm or 85 mm. Although identifying C was difficult, the length y could be measured (on the paper) to the nearest mm. Some weaker answers had added extra zeros e.g. 8.50 cm or noted a value only to the nearest cm e.g. 8 cm.
- (c) Many candidates showed repeat readings of y reflecting the difficulties involved in identifying the end C. Consequently, the absolute uncertainty for y was greater than 1 mm. Weaker answers gave the smallest division on the rule, i.e. 1 mm. When readings were repeated, some successful candidates showed the absolute uncertainty found by calculating half the range of repeated values.

- (d) Successful answers showed the magnet had been raised and second values of x and y recorded. A larger value of x should have produced a smaller distance for y if the experiment was carefully carried out. Weaker candidates found that a larger x produced a larger y .
- (e) (i) Stronger candidates showed the correct rearrangement of the equation and calculated k for both experiments. These answers demonstrated how to rearrange the equation and used $k = y\sqrt{x}$. If answers showed repeat measurements, successful answers used the latest measurements taking them through into the calculation of k . Some weaker candidates rounded in the middle of the calculations and produced inaccurate values, or did not take the latest readings through into the calculation of k .
- (ii) Successful candidates had three steps in their argument. They first state 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 20%, or could be the percentage uncertainty found in (c). Next they calculate the percentage difference between their values of k . Finally, they compare the percentage difference between their k values to the percentage uncertainty chosen and decide whether the relationship is supported or not supported. If the percentage difference between the two k values is less than the stated criterion, these successful answers then say 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.
- (f) (i) Correct answers showed that the metal plate had been removed and a new paper used to record another value of y .
- (ii) Most candidates showed the correct substitution of the y value from (f)(i) and the second k value from (e)(i) to find the x value required. Weaker candidates found the square root or inverted the equation.
- (iii) Candidates needed to be specific and relate the number of significant figures in the value of x to the number of significant figures in the value of y . Successful answers referred specifically to y (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'.
- (g) **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 other apparatus that could be used to take more accurate readings.

Successful candidates stated 'only two distances of x 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'. Some candidates went beyond the suggestion of 'take more readings' or 'take more readings and find the average' and correctly suggested 'take more readings and plot a graph'.

Successful answers identified genuine limitations. Weaker answers had ideas that were vague or could have been avoided by careful technique, such as miscounting oscillations, stands which wobbled, zero errors on a metre rule, wind affecting oscillations etc., none of which were valid problems here. Stronger candidates stated that the location of position C where the magnet stopped for a short time at the end of the 30th oscillation as a limitation. Weaker answers simply stated that the oscillations were 'fast'. Successful answers stated that a video recording could be used to more accurately locate C and needed a scale, while weaker answers suggested using a 'video with a timer' which was not actually useful here. Answers such as 'record oscillations and playback in slow motion with a timer' missed the essential need for a scale.

Aligning the magnet with line A was a difficulty as the magnet did not stay still but moved continually. Stronger candidates noted that the oscillations were often not regular as the magnet was attracted to the magnetic clamp and stand, and also noted that the use of a wooden or plastic stand would be an improvement. Weaker answers sometimes suggested the idea of covering the stand with a material such as paper in an attempt to shield the magnet from the effect of the stand, although this is unlikely to be effective.

The measurement of x was difficult but candidates needed to explain the reason for this, e.g. 'it was difficult to measure x using a meter rule because the value was 0.4 cm which was so small.' Weaker answers just stated 'it was difficult to measure x ' without a reason, and in the improvements section weaker answers suggested 'making x larger'. Better answers suggested the use of named, more precise apparatus or described a better method e.g. 'measure the thickness of several sheets of paper using vernier calipers to find the thickness of one sheet, and place sheets of paper between the magnet and strip to fill the gap'.

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 answers 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 to be given credit, and candidates should be encouraged to give detail that is specific to the particular experiment they are carrying out.

PHYSICS

Paper 9702/32 Advanced Practical Skills 2
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Key messages

- Candidates are encouraged to record all their raw data (in the table and elsewhere), show this clearly and not just state the final mean value.
- 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. They could also draw lines of best fit for data on graph paper and then use a computer to draw the line of best fit, and compare the two. 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.

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.

For many Centres, the candidates' work was of a very good standard. 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) (i) Most candidates included a unit with their value for h . A few candidates gave their value to the nearest cm rather than the nearest mm.
- (ii) Most candidates recorded a value for t in the expected range. It is probable that all candidates took repeated timings, but some recorded only a single value. Candidates should be encouraged to record all of their readings as this provides evidence that the measurements have been repeated.

- (b) Nearly all candidates recorded six or more sets of values of h and t . In a few cases, full credit could not be given because each increase in h did not produce a decrease in t .

Many candidates only increased the angle of the ramp from its initial position and so all timings were short. The strongest candidates made full use of the apparatus by also lowering the ramp to give some longer times.

Most times were recorded to the nearest 0.01 s or 0.1 s. The calculated values of $1/t^2$ were usually correct, although there were some rounding errors.

- (c) (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, d was plotted instead of h . In some cases, the points were drawn using dots that were too large. The clearest graphs used small crosses.

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.

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. 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.
- (iii) Nearly all candidates knew how to find the gradient of their line. Most took values from their line and carried out the procedure accurately and showed their working clearly, although some used too small a triangle. The intercept value was usually negative and so it could rarely be read directly off the $1/t^2$ 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. Values of a and b were sometimes given to only one significant figure. A large number of candidates included correct units for their a and b values.

Question 2

- (a) Very few problems were reported with setting up the apparatus. The measurement of the string length L usually gained credit. In some cases, no unit was given or the value was recorded only to the nearest cm.
- (b) The procedure required careful and patient adjustment of the apparatus to produce a clear pattern. Nearly all candidates gave a value for x together with its unit. Credit was also given for a value to the nearest mm and in the expected range.
- (c) There were many good answers for the percentage uncertainty in x based on an absolute uncertainty of 2 mm or more. 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) Most candidates took note of the unit given on the answer line and converted their value of L to m before calculating λ from it. A small number used their value of x instead of L .
- (e) There were many good justifications given for the number of significant figures in λ . Vague references to 'measured values' or ' L and x ' were not accepted as L was the only measurement involved in the calculation.
- (f) A complicated calculation was needed to find f but the majority of candidates carried it out successfully. In a few cases, the candidate mistakenly modified the mass per unit length μ by dividing it by the string length.

- (g) Most candidates correctly repeated the experiment using the second string.
- (h)(i) The calculation of k was correct in nearly all cases.
- (ii) Discussion of whether the analysis in (h)(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 k values with what would be an acceptable difference in this experiment. General or vague statements such as '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.
- (i) Many candidates identified the major problems associated with carrying out this particular experiment – the fact that the pattern died away quickly owing to damping of the vibrations, and the difficulty of seeing the stationary waves clearly.

The descriptions of the problems were sometimes flawed – 'fast vibrations', for example, were not a problem as they were necessary to generate the stationary pattern. Many candidates suggested the valid improvement of replaying a video recording to inspect the stationary wave (although just 'make a video' alone was not credited, as further detail was needed). In a few cases the idea of trying a contrasting background was suggested. Difficulty with gripping the hacksaw blade was also commonly listed, together with the solution of clamping the second wooden block. The difficulty of releasing the hacksaw blade with a constant force or from a constant displacement was often suggested as a source of uncertainty, but this was not credited as it would only affect the amplitude and not the wavelength of the stationary waves.

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', 'use an assistant' etc. 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 how 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
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Key messages

- Candidates are encouraged to record all their raw data (in the table and elsewhere), show this clearly and not just state the final mean value.
- 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. They could also draw lines of best fit for data on graph paper and then use a computer to draw the line of best fit, and compare the two. 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 V_1 and V_2 to the nearest 0.01 V with units, and set up the circuit correctly so that V_2 was greater than V_1 . Some candidates omitted units, gave the wrong units (Ω or A) or gave inconsistent readings with one voltage value to the nearest 0.01 V whilst the other was to the nearest 0.001 V. In some cases the circuit was incorrectly set up, giving a value of V_2 that was smaller than V_1 .

- (b) Many candidates were able to collect six sets of values of x , V_1 and V_2 without assistance from the Supervisor, and usually showed a correct trend in their values. Some candidates needed help setting up the circuit. A minority of candidates took 7–10 sets of results and then did not plot all their observations on the graph grid. Few candidates took the time to repeat their readings. This may have helped to identify anomalous results and improve data quality. If time is limited, candidates should be encouraged to look out for possible outliers which do not fit a general trend and repeat these readings to double-check.

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 length provided and use at least 10.0–70.0 cm. A small minority chose an impractical range of 5 cm or 10 cm, whilst other candidates went up to 100 cm but only started at 50 cm.

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 last V_1/x column. A few candidates used confused notation, giving the units as V/cm^- instead of $V\text{ cm}^{-1}$.

Many candidates correctly recorded their raw values for x to the nearest 0.1 cm. Some candidates stated their measurement to the nearest cm e.g. 20 cm without considering that they can make the measurement to the nearest mm using the ruler provided. A few candidates stated measurements with too many trailing zeros, e.g. 20.00 cm.

Many candidates correctly recorded their calculated values for V_1/x 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 V_1/x 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 raw values and just showed two columns of calculated values. Candidates should be encouraged to record their raw values.

- (c) (i) A few candidates plotted the wrong graph or omitted labels. Compressed scales (in either the x or y direction) were often seen and could not be awarded credit. There were many incidences 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.

- (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) 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.

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

- (d) Most candidates recognised that P was equal to the gradient and Q was equal to the intercept calculated in (c)(iii). Some candidates recorded a value with consistent units for P (m) and Q (V). Some candidates stated incorrect units or omitted the units.

Question 2

- (a) Most candidates measured values of L in the appropriate range, with a unit and to the nearest mm. Some candidates omitted units, whilst others stated the length measurement to the nearest cm and a few stated a value that was not in range.
- (b)(i) Many candidates stated the angle to a tenth of a degree (e.g. 13.2°) when the precision of the protractor did not justify this, and some gave an incorrect unit (e.g. $^\circ\text{C}$). Some candidates either did not read the instruction correctly or misread the protractor, giving an angle of around 75° instead of 14° .
- (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. A few candidates incorrectly divided their uncertainty by 360° rather than their own value of A .
- (c)(i) Many candidates gave a value for T in the appropriate range and with a unit, and showed evidence of repeated timings of five or more oscillations. Some candidates did not repeat sets of readings, measured only one oscillation, found short times (suggesting $\frac{1}{2}T$ was measured rather than T), or determined frequency instead of period. There were some cases of omission of units or very small times e.g. 0.14 s suggesting misreading of the stop-watch.

A significant number of candidates probably measured the time for 10 oscillations but did not divide their answer by 10 (and did not give evidence that 10 oscillations were in fact measured).

- (ii) Many candidates correctly calculated d . Some candidates incorrectly rounded this value. A minority of weaker candidates incorrectly used their calculator in radian mode.
- (iii) Many candidates correctly justified the number of significant figures they had given for the value of d with reference to the number of significant figures used in A . Many candidates gave reference to just 'raw readings' or 'values in calculation' without stating what these values were, related their significant figures to $\sin A$ and not the raw angle A , or incorrectly related to a different reading e.g. T or L .
- (d) Most candidates recorded second values of A and T . Most candidates recorded a second T that was greater in value than their first value at the smaller angle, gaining credit for quality.

- (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 A and 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 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, or the string was too thick to read the protractor. Also commonly seen were reasons relating to the difficulty in measuring the length of the pendulum, e.g. it was difficult to locate the centre of the bob, or the cork was in the way of the ruler. To gain credit, the quantity that was difficult to measure must be specified along with the difficulty. Just 'parallax error' or 'difficult to measure to the centre of the bob' on its own does not gain credit without linking to the angle or length L quantity respectively.

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 fiducial marker' (without stating where to place it), '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 how 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
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Key messages

- Candidates are encouraged to record all their raw data (in the table and elsewhere), show this clearly and not just state the final mean value.
- 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. They could also draw lines of best fit for data on graph paper and then use a computer to draw the line of best fit, and compare the two. 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

In **Question 1**, candidates are usually expected to collect data and plot a graph using quantities derived from the data. The experiment will sometimes be electrical in nature, as was the case on this paper. If candidates have difficulty assembling the circuit or suspect that the circuit is not behaving in the way anticipated, they should be encouraged to seek assistance from the Supervisor. The Supervisor can then check that the circuit is connected correctly, change it if necessary, and check that any meters in the circuit are functioning properly. 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.

Many candidates record experimental values that are unrealistic. For example, when asked to record the period of a mechanical oscillator with a period of approximately 2.0 s, some candidates record instead the time for 10 oscillations, forgetting to divide their value by 10. Others record a value of less than 0.01 s, having misread the display on the stop-watch. It is good practice to first reflect on what the approximate value of an experimental measurement is likely to be and then check this estimate against the actual measured value. In this way, candidates should gain a 'feel' for likely experimental values.

Measuring and calculating mass is a further example. In **Question 2** on this paper, candidates were asked to calculate the total mass of a bottle containing 500 cm³ of water, 200 g of slotted masses and a 100 g mass hanger. Just holding the bottle and feeling its weight should give candidates a rough idea of what the value is. Candidates recording values less than 1.0 g or several hundred kilograms could have then identified that an error had been made.

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.

The general standard of the work done by the candidates was good, with 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_S that was in the range 2.00–4.00 V. Some candidates omitted a unit.
- (b) Most candidates correctly recorded a value of V that was less than their value of V_S . Fewer candidates repeated their measurements to find an average value.
- (c) Almost all candidates were able to record six sets of values of n and V successfully, showing the correct trend.

Few candidates made the best use of the possible range of values of n . The minimum possible value for n was zero (i.e. no capacitors connected to the component holders) and the maximum value for n was 10 (combining all the available capacitors in parallel). To be awarded credit for the range, candidates needed to have a minimum value for n of 0 or 1, and a maximum value for n of 7 or more.

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

Most candidates recorded all their raw values of V to the nearest 0.01 V (or all to the nearest 0.001 V). 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 digital voltmeter), and not necessarily to the same number of significant figures.

Most candidates calculated and recorded their values of $1/V$ correctly, i.e. to the same number of significant figures as (or one more than) the number of significant figures of the raw values of V . A few candidates rounded their final answers incorrectly.

- (d)(i) Candidates were required to plot a graph of $1/V$ on the y -axis against n on the x -axis. Most gained credit for drawing appropriate axes, with labels and sensible scales. The values of n being integer values made the choice of a scale on the x -axis, and the correct plotting of the points, relatively straightforward.

Some 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. Although this appears to make good use of the graph grid, it invariably makes it very difficult to plot all the points correctly. Credit cannot be awarded for the scale, and these candidates often lost further credit later for incorrect read-offs when calculating the gradient or the y -intercept of the line. A few candidates chose non-linear scales, or scales which meant that one or more points were off the graph grid.

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 can improve by plotting the points more accurately i.e. to within half a small square.

The majority of candidates were able to collect a set of data that was awarded credit for quality.

- (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. Others tended to join the first and last points on the graph, regardless of the distribution of the other points, or draw a line which could clearly be improved by rotation. A few candidates drew a double line or a line with a 'kink' in it (perhaps by using a small ruler).
- (iii) Many candidates used a suitably large triangle to calculate the gradient, gaining credit for correct read-offs and substitution into $\Delta y/\Delta x$. Others 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 $\Delta x/\Delta y$), or check that the triangle for calculating the gradient was large enough (the hypotenuse should be greater than half the length of the line drawn) in order to gain credit.

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 can be used only 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 V^{-1}). Others omitted the units for a and b .

Question 2

- (a) Most candidates calculated the value of M correctly.
- (b)(i) Most candidates were able to record a value for the period T of the oscillations in the range $0.50\text{ s} \leq T \leq 1.00\text{ s}$, although some misread the stop-watch. Fewer candidates repeated their measurement of the time for multiple oscillations. Measuring the time for one oscillation several times is not good practice. As a general rule, the time for at least 5 complete oscillations should be repeated two or three times, and a mean value calculated. All working should be shown, including the value of n , where n is the number of oscillations.

Several candidates forgot to divide their average value of nT by n to find T .

- (ii) Candidates were asked to estimate the percentage uncertainty in their value of T . Most were familiar with the equation for calculating percentage uncertainties, but many underestimated the absolute uncertainty in the value of nT . This is dependent not only on the precision of the stop-watch, but also on the possible errors in judging the beginning and end of an oscillation. A realistic estimate for the absolute uncertainty in the measurement of the raw value(s) of time is 0.2–0.5 s.
- (c)(i) Most candidates recorded a second value of M successfully.
- (ii) Almost all candidates recorded a second value of T , and the majority obtained a value for T which was greater than the value recorded in (b)(i).
- (d)(i) Most candidates were able to calculate the two values for k correctly. Some candidates were not awarded credit because they calculated $1/k$ or recorded values on the answer line to only 1 significant figure.

- (ii) Candidates were asked to explain whether their results supported a suggested relationship, i.e. after 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)(ii) 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' which is insufficient – a numerical percentage comparison is needed.

- (e)(i) The majority of candidates were able to record value(s) for D to the nearest mm and in the appropriate range. Some only recorded their raw values for D to the nearest cm, or recorded their value for D on the answer line in cm rather than m.
- (ii) Most candidates were able to calculate the value of A successfully.
- (iii) Most candidates calculated ρ successfully, though some candidates used the first value of k or an average value rather than the second value of k .
- (f) Many candidates recognised that two sets of data were insufficient to draw a valid conclusion, though some confused conclusions with results. In this experiment, the main difficulties included problems getting the bottle to oscillate vertically (the bottle would tilt to one side when oscillating and sometimes hit the side of the bucket) and judging the exact moment the bottle starts or completes an oscillation. Also the measurement of M excluded the mass of the bottle itself.

Some candidates simply described measurements that were difficult to make without explaining why they were difficult e.g. 'it was difficult to measure D ' or 'difficult to measure T '. A reason for the difficulty is also needed to gain credit, e.g. 'it was difficult to measure D accurately because the plastic was flexible, deforming when held/the cross-section of the bottle was not a perfect circle/ D was not constant along the length of the bottle'.

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

Other good answers included:

- using an electronic balance to measure M , or a measuring cylinder to measure the water volume
- fix the masses with tape to the bottom of the bottle or use an alternative to the slotted masses and mass hanger e.g. lead shot, sand or a single large mass
- record a video of the experiment, then playback using the video recorder's clock to measure the period of the oscillations
- measure the diameter D in three different directions and calculating an average value/use vernier calipers.

PHYSICS

Paper 9702/35 Advanced Practical Skills 1
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Key messages

- Candidates are encouraged to record all their raw data (in the table and elsewhere), show this clearly and not just state the final mean value.
- 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. They could also draw lines of best fit for data on graph paper and then use a computer to draw the line of best fit, and compare the two. 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 value z to the nearest 0.1 cm with units and set up the apparatus correctly so that y was less than 35.0 cm. Some candidates omitted units, or gave readings to the nearest cm.
- (b) Many candidates were able to collect six sets of values of x and y without assistance from the Supervisor, and showed a correct trend in their values. Some candidates needed help setting up

the apparatus. A minority of candidates took 7–8 sets of results and then did not plot all their observations on the graph grid. Few candidates took the time to repeat their readings. This may have helped to identify anomalous results and improve data quality. If time is limited, candidates should be encouraged to look out for possible outliers which do not fit a general trend and repeat these readings to double-check.

Many candidates chose too small a range over which to conduct the experiment and so the values ended up too close together. It was common for all values of x to be positive, but candidates needed to include negative values as well to make full use of the apparatus (i.e. x values to the left of the 50.0 cm mark). It is expected that candidates consider the whole length provided.

Many candidates were awarded credit for the column heading, 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.

Many candidates correctly recorded their raw values for x to the nearest 0.1 cm. Some candidates stated their measurement to the nearest cm e.g. 20 cm without considering that they can read to the nearest mm using the ruler provided. A few candidates stated measurements with too many trailing zeros, e.g. 20.00 cm.

Overall the table work was done well by candidates. Even those who sought the help of the Supervisor in setting up the apparatus usually gained credit for the table.

- (c) (i) A few candidates plotted the wrong graph or omitted labels. Compressed scales (in either the x or y direction) were often seen and could not be awarded credit. There were many incidences 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 straight 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.

- (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.

Candidates should be encouraged to draw the line according to the positions of the plotted points, and not to force the line through the origin.

- (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.

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

- (d) Most candidates recognised that A was equal to the gradient and B was equal to the intercept. Stronger candidates recorded a value with consistent units for B (m) and no units for A . Weaker candidates stated incorrect units e.g. B (m^{-1}) or A (m) whilst many others omitted to give units for B .
- (e) Many candidates were able to calculate p using one or both equations provided.
- (f) Some candidates were able to draw line W with the same gradient and a lower value of y -intercept. Some candidates drew lines with different gradients and a few candidates used the same gradient but a higher value of y -intercept.

Question 2

- (a) (i) Many candidates stated a value for T in the appropriate range with a unit, and showed evidence of repeated timing of five or more oscillations. Some candidates did not repeat sets of readings, measured only one oscillation, or determined frequency instead of period. There were some cases of omission of units or very small times e.g. 0.12 s suggesting misreading of the stop-watch.
- (ii) Many candidates correctly calculated f . Some candidates incorrectly rounded this value. A minority of candidates having incorrectly calculated f as T in (i) then inadvertently calculated T here.
- (iii) Many candidates correctly justified the significant figures they had given for the value of f , with reference to the number of significant figures used in raw time, nT or T . Many candidates gave reference to just 'raw readings' or 'values in calculation' without stating what these values were.
- (b) (i) Most candidates measured a value of n .
- (ii) Most candidates were able to measure a value of the current. Some candidates had difficulty in taking a reading but still gained credit for writing what their meter reading stated, e.g. 0.0 μA or 0.1 μA . A few candidates left the space for their answers blank and so could not be awarded credit. Any difficulties with the experiment must be reported by the Supervisor on the Supervisor's Report so that the Examiners can take this into account.
- (iii) 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 I given that it was a fluctuating reading. Some candidates repeated their readings and correctly gave the uncertainty in I as half the range, while other candidates did not halve the range.
- (c) (i) Nearly all of the candidates correctly recorded a second value of T that was larger for the larger mass.
- (ii) Most candidates recorded second n and I values for the tube with fewer turns and recorded a value less than their first value.
- (d) (i) Many 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 back to the percentage uncertainty calculated for I and this was also credited. Some candidates omitted a criterion. Other candidates gave a general

statement such as 'this is valid because the values are close to each other' which was not credited as there was no justification for the conclusion.

- (e) This experiment provided many limitations and improvements to write about, ranging from the measurements to the practical difficulties of setting up and getting a set of readings. 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. To gain credit for limitations concerning measurements, the quantity that was difficult to measure must be referred to along with the difficulty. For example, 'it was difficult to measure n as it is not a whole number' or 'difficult to measure the current because it was so small'. Solutions such as 'use a centre zero analogue meter' and 'use more turns' gained credit. Credit was awarded for difficulty in the setup e.g. 'tube fell over', 'magnet hit the tube', together with stated methods of improvement such as 'clamp tube to table' and 'use a wider tube'.

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 stand', 'use fiducial marker' (without stating where to place it), 'attach spring to rod' (without specifying how to do this) 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 how these difficulties impact on the experiment. Candidates should then try to think of associated solutions that address each of these problems.

PHYSICS

Paper 9702/41 A Level Structured Questions

Key messages

- It is important that candidates use technical language accurately. In this paper, the words that candidates often confused were 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. There were several questions on this paper where a significant number of candidates gave answers to questions that were not asked, but have been asked in recent past papers. Candidates should be advised not to rely heavily on memorising previous mark schemes.

General comments

In general terms, candidates scored well on traditional questions involving 'bookwork' and not as well on questions requiring application of knowledge. Working was nearly always shown, which is encouraging, and the use of English was very 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 may depend on the explanation.

Comments on specific questions

Question 1

- (a) This statement of Newton's law of gravitation was well-known. A significant number of candidates did not mention point masses.
- (b)(i) Only the strongest candidates were able to answer this question correctly. Many candidates incorrectly thought that the planets were in equilibrium, either because the speed was constant, the forces on each planet and the star were equal and opposite, or because the gravitational and centripetal forces were equal. It was also quite common for a candidate to state that the planets were not in equilibrium because the radii, masses or forces were different.
- (ii) 1. This was generally answered correctly by most candidates.
2. Few candidates gained full credit here by demonstrating that they had used the data for more than one planet. Most candidates used data for only the first planet in the list. Some candidates did not look at the column headings carefully and squared the data for T^2 , hence leading to an incorrect answer for the mass.

Question 2

- (a) (i) Some responses stated that a was directly proportional to y and a was in the opposite direction to y , but without explaining how the graph showed this. Some omitted the phrase 'through the origin'.
- (ii) This calculation was completed well. There were a few power-of-ten errors caused by not converting the displacement from mm into m. Some of the least able candidates started with the incorrect formula $a = \omega x$, which could not be awarded credit.
- (b) (i) Candidates who had encountered this idea before found it easy to gain full credit. The displacement in simple harmonic motion has both positive and negative values. If a position is being stated, it is important to be precise with terminology: 'maximum displacement/amplitude' could not be awarded credit as there was no direction specified.
- (ii) Common errors were to use an acceleration of 4.5 ms^{-2} as this was the end of the line on the graph, or 5.0 ms^{-2} as this was the maximum value on the acceleration axis.

Question 3

- (a) (i) The weakest candidates often gave answers in terms of the first law of thermodynamics (internal energy is the work done plus heat supplied). Weak candidates who avoided doing this tended to answer in terms of the sum of kinetic energy and potential energy of the system, but without specifying that they meant the energies of the molecules.
- (ii) Candidates were either quite familiar with this idea and knew how to relate the change in internal energy to the change in thermodynamic temperature, or they were not sure at all and again made reference to the first law of thermodynamics.
- (b) A simple approach was to use $pV = NkT$ and substitute. Most candidates chose to use $pV = nRT$ to find n and then used $N = nN_A$ to find N . Some candidates made power-of-ten errors in converting the volume or thought they had reached the final answer when they had found n , the number of moles.

Question 4

- (a) This question was well answered, and a variety of correct answers were given.
- (b) It was quite common for weaker candidates to give long-winded and unnecessary descriptions either of how an ultrasound transducer works or general descriptions of the medical diagnoses possible using ultrasound. Candidates should be reminded to read the question carefully and focus their answers on the specific question being asked.

Common mistakes included:

- not mentioning that the ultrasound is sent into the body as pulses,
- not stating that the time delay between and the relative amplitudes of the transmitted and reflected pulses gives information about the depth and nature of the **boundary** between the body's structures, not the structures themselves,
- not adequately explaining the purpose of the coupling gel.

Question 5

- (a) (i) This was well answered. Candidates need to be specific when referring to the direction of rotation, e.g. 'the same direction as the rotation of the Earth'. Clockwise/anticlockwise could not be awarded credit as these depend on where the observer is.
- (ii) This question asked for the position of the satellite. Some candidates gave 'stationary' but this is a description of the velocity relative to the Earth rather than the position.
- (iii) Candidates either needed to recall a frequency here or use their knowledge of the electromagnetic spectrum. Some weaker candidates calculated the frequency associated with a time period of 1 day, i.e. confused the communication frequency with the orbital frequency.

- (b)(i) Many candidates arrived at a correct signal power having used $195 = 10 \lg(3000/P)$. Weaker candidates often found a very large signal power having incorrectly used $195 = 10 \lg(P/3000)$.
- (ii) Explaining the need for different frequencies for the up-link and down-link was less well done. A common misconception amongst weaker candidates was that the signal's frequency rather than its power became attenuated during propagation. Stronger candidates grasped the concept that the attenuated up-link signal would be swamped by the amplified down-link signal if the frequencies were the same, but weaker candidates' responses often had a lack of clarity over which signal was being swamped. Unclear phrases such 'swamping between' and 'swamping with' were quite common.

Question 6

- (a) The majority of candidates knew this definition.
- (b) Correct answers were common. Some candidates made the task harder than it needed to be by first calculating V using $V = E \times d$ and then using $Q = V \times 4\pi\epsilon_0 d$. Some candidates made arithmetic mistakes or forgot to convert centimetres to metres. Weaker candidates who had incorrectly explained field strength tended to use $Q = E \times 4\pi\epsilon_0 r$ to calculate a value for Q .
- (c) Many candidates did not give answers in terms of Q . Answers of 4.5×10^{-7} without a unit were quite common. The weakest candidates tended to give an answer of 6.0×10^{-7} , not having subtracted Q .

Question 7

- (a) Candidates found it difficult to give a definition that applies to this specific situation. They often understood the definition of capacitance, but the question was asking for the definition as specifically applied to the parallel plate capacitor, so more detail was needed. There was some confusion between a parallel plate capacitor and capacitors connected in parallel.
- (b)(i) Most candidates answered this correctly.
- (ii) Many candidates found it difficult to understand how the circuit functions and could not gain credit. A common incorrect answer was to divide the answer in (b)(i) by 2 rather than 50.
- (iii) Many candidates realised that they needed to divide their previous answer by 120.
- (c) If a second capacitor of equal capacitance is placed in series with the first, then the capacitance is halved. Therefore, the current is halved. Many candidates said that the two quantities decreased, but it was possible to be more specific than this. If values are given in the question, then candidates should be encouraged to make full use of them.

Question 8

- (a) The most common creditworthy description of negative feedback was of the form 'negative feedback is when some of the output voltage is fed back to the inverting input of the amplifier'. Weaker candidates would tend not to state which input the voltage was fed back into.
- Some of the weakest candidates tended to write down everything they could remember about op-amps and quite often contradicted themselves. Some weaker candidates also tended to get things backwards, e.g. 'negative feedback increases the gain and reduces the bandwidth'. Some candidates were not clear about the difference between open-loop and closed-loop gain and gave 'reduced open-loop gain' as an incorrect answer.
- (b)(i) Candidates generally calculated the gain correctly, although a significant number worked out the gain (correctly) as -12 and then wrote 12 on the answer line. This is an inverting amplifier circuit and the gain should be negative.
- (ii) This was usually answered correctly. A common mistake was to forget that the power supply to the op-amp was 6 V and that the output cannot be greater than this value.

- (iii) Many candidates stated that one of the resistors should be swapped for a light-dependent resistor (LDR) but did not state which resistor should be replaced.

Question 9

- (a) Candidates generally realised that there was a force on the wire and usually worked it out as being upwards. Many candidates did not read the question correctly and gave the force on the wire rather than the force on the magnets.
- (b) (i) This calculation was straightforward, and the majority could recall that $F = BIL \sin \theta$. A few weaker candidates overlooked that the flux density was in mT and their final answer was incorrect by a factor of 10^{-3} .
- (ii) Most candidates were correct. A common incorrect answer was $1.85 \times 10^{-3} \text{ N}$ as candidates divided by $\sin 60^\circ$ but forgot to multiply by $\sin 60^\circ$ as well.
- (c) A few candidates did not draw an alternating waveform. Whatever waveform candidates drew, it was common for weaker candidates to draw less than two cycles, and to omit to put any values on the axes. Some of the stronger candidates could have improved their answers by taking more care when sketching their waveforms and ensuring that the waveform does not have different positive and negative amplitudes or a changing time period.

Question 10

- (a) Most candidates gained credit for this definition.
- (b) This question proved to be difficult. Many candidates could state Lenz's law but found it difficult to assemble a reasoned argument. Some candidates gave an answer formed around the idea that the ring jumps upwards because 'the e.m.f. in the ring opposes the e.m.f. in the coil'. Some of the stronger candidates did understand the notion of two opposing magnetic fields resulting in an upward force on the ring, but were unable to come up with a convincing argument in support of this. The strongest candidates wrote well-reasoned explanations and were awarded full credit.

Question 11

- (a) (i) Most candidates were awarded credit, although the word energy was sometimes missed out.
- (ii) Candidates found this question difficult. The question was asking for evidence and the answers of many candidates were not focused on evidence.
- (b) Some weak candidates answered in terms of the electrons in the photoelectric effect, and used phrases such as 'work function' and 'threshold frequency' that were not relevant to the question. Some candidates did not understand the one-to-one relationship between a photon and an electron, and instead constructed arguments based on the absorbed photons making the material warmer and this making the electrons more energetic. It would be helpful to emphasise further the idea of the one-to-one interaction to these candidates. Other weaker candidates tended to state that electrons absorbed energy directly from the incident light without using photons in the explanation, and had electrons 'jumping over' the forbidden band without a sense of which direction they were jumping in.

As with previous explanations, strong candidates could provide a clear explanation.

Question 12

- (a) (i) Most candidates understood the question. Some candidates gave answers to 1 significant figure when the data were given to 2 significant figures.
- (ii) The effect of passing through more than one material was not well understood, and some candidates incorrectly added, subtracted or occasionally divided the exponential decay terms.

- (b)(i) The weakest candidates thought that contrast had something to do with image clarity or sharpness. Whilst most candidates knew it had something to do with image brightness and darkness, many found it difficult to express this. Only a few stated it was the difference in the degree of blackening between structures.
- (ii) Weaker candidates tended to ignore the values they had just calculated, and instead referred to the absorption coefficients rather than the relative differences in transmitted intensity between soft tissue and a combination of bone and soft tissue.

Question 13

- (a) Candidates found it difficult to give a complete answer. Radioactivity is a nuclear process. Some answers contained descriptions of fission or did not mention that particles/radiation was emitted. The key words 'unstable' and 'spontaneous' were often missing.
- (b)(i) Some weaker candidates incorrectly calculated the activity as the gradient of a line drawn from the origin to the curve at $t = 14$ minutes. The easiest way to answer the question was to draw a tangent at 14 minutes and then to find the activity as the gradient of the tangent. Another approach was to find the half-life and work out the activity from it.
- (ii) Most candidates gained credit for this question.

PHYSICS

Paper 9702/42 A Level Structured Questions

Key messages

- It is important that candidates use technical language accurately. In this paper, the words that candidates often confused were 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. There were several questions on this paper where a significant number of candidates gave answers to questions that were not asked, but have been asked in recent past papers. Candidates should be advised not to rely heavily on memorising previous mark schemes.

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 score well.

Some candidates relied heavily on answers that had been memorised but were not relevant to the question being asked in **Questions 1(a)(i), 1(a)(ii), 3(a), 7(a)(i), 9(a) and 12(a)**.

There was no evidence that candidates who were properly prepared for the examination had insufficient time in which to complete the paper.

Comments on specific questions

Question 1

- (a) (i) Many candidates answered this question as if answering a question about the meaning of a gravitational field or about Newton's law of gravitation. Of those who did recognise that the question addressed the meaning of the lines of gravitational force, only a small number were able to express that the lines represented the direction of the force on a mass placed in the field.
- (ii) Few candidates recognised that they were asked to give an explanation in terms of lines of gravitational force. Many gave an equation for the gravitational field strength due to a point mass and answered in terms of the variables in this equation, but such responses did not answer the question asked. Of candidates who did discuss lines of force, most were able to state that the lines of force are radial. Explanations of why radial lines can be approximated as parallel lines close to

the surface of a planet with large radius were uncommon. More candidates were able to explain the implications of parallel field lines for constant field strength.

- (b) There were many ways of answering this question. The expected starting point, whichever approach was chosen, was to realise that the threshold for escape is when the kinetic energy of the rock exceeds the potential energy required to reach infinity. From there, calculation of a relevant quantity was expected, finally leading to a comparison between the threshold value and the actual value to lead to the conclusion that the rock escapes into space. The most common valid method used was to calculate the escape velocity of the Moon to be 2.4 km s^{-1} and to compare this with the actual velocity of the rock of 2.8 km s^{-1} . An approach that calculated and compared kinetic and potential energies was also commonly seen.

A common error was to calculate the orbital velocity of the Moon and equate forces (gravitational and centripetal forces) rather than energy.

Question 2

- (a) Most candidates were able to link the absence of potential energy with the assumption of the kinetic theory that the forces between molecules in an ideal gas are negligible. Some candidates contradicted themselves by listing more than one assumption. Others muddled their answers by talking about the forces within the molecules or the forces between atoms, neither of which could be awarded credit.
- (b)(i) Most candidates were able to give a correct description of the meaning of $\langle c^2 \rangle$. Common incorrect answers were 'root mean square speed' and 'mean speed squared' of molecules. A few gave an answer in terms of the gas rather than its molecules.
- (ii) This question was generally well-answered. Some candidates did not establish that T represents absolute temperature and some referred to a change in temperature rather than absolute temperature.
- (c)(i) 1. This question was well-answered by many candidates. The strongest candidates started with the most immediately relevant equation $pV = NkT$, but most determined the number of moles first. A significant number of candidates calculated the number of moles but then stopped.
2. Many candidates realised that the 2900 J input of thermal energy, in a constant volume change, represented the increase in internal energy of the gas (and therefore the total increase in kinetic energy of the particles of the gas). Often, these candidates then gave 2900 J as the average increase in kinetic energy per molecule without pausing to consider the plausibility of this answer.
- (ii) Candidates were expected to equate their answer to (c)(i) part 2 with $(3/2)kT$ to calculate a temperature increase and then add this to the initial temperature. Candidates starting from 2900 J arrived at an implausible final temperature but were awarded credit if all of the working was clear.

Question 3

- (a) Candidates at this level need to be clear and accurate in their use of terminology and to avoid colloquial language such as 'overcoming forces'. Credit was available for establishing why there is a need for an input of energy. It was not possible to gain full credit without reference to particles in some form – firstly by discussing the need to break bonds, or weaken forces, between molecules and secondly by establishing that during melting the potential energy of molecules is increased. Credit was also awarded for explaining that, because the volume of the substance does not change, the required input of energy cannot be through work being done on the system and so it must be provided by thermal energy.

A significant minority of candidates misread the question and gave an explanation of why the temperature does not change during melting.

- (b)(i) Most candidates were awarded credit for giving the correct equation relating thermal energy input to temperature change, and many were also able to show how this equation applied to the loss of energy from the water and from the can in cooling from 38°C to 23°C to give the required value. Common errors were to add the two masses together before applying the equation or to use absolute temperatures rather than temperature changes.

- (ii) It was less common to see candidates realise that the loss of energy in (b)(i) was used partly to raise the temperature of the ice, both before and after melting, as well as to provide the latent heat needed to melt the ice. Partial credit was available to candidates who took account of the rise in temperature in one of the two stages (either from -18°C to 0°C using the specific heat capacity of ice, or from 0°C to 23°C using the specific heat capacity of water).

Question 4

- (a) The defining properties of simple harmonic motion were well-known by many candidates.
- (b)(i) 1. Many candidates were able to identify the damping as light damping, and to explain this in terms of either continuing oscillation or gradual decrease in amplitude. Common mistakes were to conflate displacement with amplitude or to conflate exponential with gradual. Candidates who gave 'exponential decrease in amplitude' as the justification for light damping appeared to not appreciate that the decrease in amplitude is exponential in all three forms of damping.
2. Many candidates were awarded credit for discussing either the nature of the resistive forces acting on the mass or the loss of energy from the system. A common misunderstanding was that the springs cause the damping and that energy stored in the springs is lost from the system.
- (ii) 1. This question was answered fully and well by very many candidates. Common mistakes were to neglect the conversion of the mass of the trolley to SI units or to forget the square root at the end of the calculation. The most common fundamental error was to start from $a = -\omega x$ (and hence to deduce $\omega = 2k/m$) rather than $a = -\omega^2 x$.
2. Many candidates successfully deduced the period of the oscillations from their value of ω . A smaller number realised that time t_1 represents 1.5 periods.

Question 5

- (a)(i) The basic meaning of bandwidth as a range of frequencies was generally well-known by many.
- (ii) It is essential, with questions such as this, that candidates appreciate the comparative nature of what is being asked. Statements such as 'good quality' and 'limited number of stations' are meaningless unless referenced to a standard, and in the absence of any reference point are equally true for all bandwidths. For example, the number of stations that can be fitted into a frequency range is 'limited' for all bandwidths. The difference for waves of greater bandwidth is that the number is more limited. Responses needed to be comparative in nature.
- Some candidates discussed quality of sound rather than quality of signal and some asserted that 'more information' could be carried without any reference to time rate. A common error with the disadvantage was to relate fewer stations to area on the ground rather than to a region of the frequency spectrum.
- (b)(i) This part was universally well-answered by candidates who clearly understood frequency modulation.
- (ii) Partial credit was available to candidates who showed some understanding of the concept of frequency deviation, but who used 5 V rather than 3 V as the voltage variation. Some candidates showed a lack of understanding of this topic by using either the raw frequency deviation figure or the frequency of the signal wave and using one of those as the basis of the frequency modulation.
- (iii) Candidates found this question difficult. Many candidates did not calculate the period. Most of the candidates who worked out the period did not appreciate that the time between maximum and minimum frequency is half the period.

Question 6

- (a) Many candidates were able to identify the defining equation of capacitance as the ratio of charge to potential. It is worth emphasising to candidates that definitions in terms of units, when a question is

asking for the definition of a quantity, cannot be awarded credit. The use of equations requires definition of the terms in the equation.

- (b) This question asked for circuit diagrams showing how three capacitors can be connected, so credit could be awarded only when the components drawn were clearly capacitors and three in number. Answers showing resistors or combinations of six capacitors were common from weaker candidates. Most candidates who knew the topic were able to answer successfully, provided it was made clear in some way between which points the capacitance had the required value.
- (c) (i) Calculation of the combined capacitance of the two capacitors in series was done well by many candidates. Common errors were to combine them in parallel rather than series, to forget to take the reciprocal at the end, or to get as far as $6/5$ but to neglect to carry out the final calculation.
- (ii) 1. Most candidates were awarded at least partial credit, and many deduced the $9.6 \mu\text{C}$ figure. Having arrived at the 'correct' answer, some candidates did not appreciate that the total charge for capacitors connected in series is the same as the charge on each capacitor, and attempted to apply some sort of ratio to their $9.6 \mu\text{C}$ figure.
2. Many candidates were awarded full credit. Some candidates who started off with $E = \frac{1}{2}CV^2$ then incorrectly used 8 V as the p.d. across the $3 \mu\text{F}$ capacitor.

Question 7

- (a) (i) The concept of feedback in general was well-known by most. Very few candidates attempted to explain the 'negative' aspect of the question, and those who did often answered in terms that were specific to the operational amplifier rather than addressing the concept of negative feedback in principle.
- (ii) It was important for candidates to appreciate the comparative nature of what was being asked. For example, it was common to see responses suggesting that negative feedback will result in 'no saturation'. It is possible for an amplifier to become saturated even with negative feedback, and the point about negative feedback is that it makes saturation less likely (or occur over a narrower range of input voltages).
- (b) (i) The formula for the gain of a non-inverting amplifier was well-known and successfully applied by many candidates. A common error was the use of the inverting amplifier formula instead. Some candidates incorrectly gave their gain with units of V.
- (ii) Use of the gain calculated in (b)(i) to calculate the output voltages in this part was often done well. The most common mistakes were incorrect signs and a lack of understanding that, for output voltages above 9.0 V, the amplifier would become saturated.
- (iii) A small number of candidates answered this question successfully. Of the candidates who did identify that a thermistor was required, only a small number accurately identified where in the circuit it needed to be placed.

Question 8

- (a) Credit could be awarded based on the required points being evident in a diagram. However, it was rare to see diagrams that added to the quality of an answer. Many candidates put time and effort into producing neat and tidy diagrams that were unable to score credit on account of being inadequately labelled, so it is important to encourage candidates to label their diagrams. It was more common for the relative orientation of the two fields, and the velocity of the particle relative to the fields, to be being credited on the basis of the point being explicitly made in the narrative.

Many candidates gave full and detailed explanations of how a particle can pass through the region of the fields undeviated, but did not go on to make it sufficiently clear that this only happens for particles with a particular velocity.

- (b) This question was well-answered, with a large number of candidates able to score full credit. Many other candidates were able to show that the mass was $3.3 \times 10^{-26} \text{ kg}$ but then stopped short of showing the division by 1.66×10^{-27} to reach 20 u. A small number of candidates used the mass of

a proton rather than the unified atomic mass unit, and some did not demonstrate awareness of the need to convert the diameter to the radius.

- (c) This part was well-answered by many candidates. Common errors were to draw semicircles with smaller rather than larger radius and to take insufficient care over the drawing of the semicircle. Such responses showed paths that either did not pass through the slit, or were not semicircular, or remained on the original path for too long.

Question 9

- (a) This question gave candidates the opportunity to receive credit for some basic 'bookwork', and most candidates were successful. Some candidates answered a completely different question, and instead gave a description of Faraday's law of electromagnetic induction. Some gave a formula but did not define the symbols used in it. Others conflated flux and flux density, and some gave responses that contradicted themselves by giving two definitions, one of which was incorrect.
- (b) This part was well-answered, with many candidates receiving full credit. It was a 'show that' question, which meant that candidates did need to show the working clearly for the calculation of the cross-sectional area in order to be able to access full credit.
- (c) Many candidates were awarded at least partial credit. Most realised the times between which the induced e.m.f. will be zero, and many realised that the non-zero parts of the graph are stepped. The stronger candidates were able to show the steps at the correct magnitudes, appreciating that the second change, providing for the same change of magnetic flux linkage over half the time, will result in an induced e.m.f. of twice the magnitude of the first. Fewer candidates realised that both sloping parts of the B - t graph had the same sign of gradient, so the two steps should each show an e.m.f. of the same polarity.

Question 10

- (a) Many candidates were able to describe the photoelectric effect as the emission of electrons when electromagnetic radiation is incident on a surface. In some cases, although electromagnetic radiation was mentioned, it was not clear enough that it is incident on a surface. A few candidates were confused and talked about emission of photons from the surface.
- (b)(i) The identity of a photon as a packet of energy was generally well-known. The idea that this energy is quantised energy of electromagnetic radiation was less well understood. A significant minority of candidates thought that electromagnetic waves 'carried' the photons rather than the photons being the electromagnetic energy in packets. The most common error from candidates who did have the right idea was to miss out the crucial reference to energy.
- (ii) This question was well-answered by many candidates. The relationship between photon energy and wavelength was generally well-known, and most candidates who knew the relationship were able to carry out the calculation correctly. Irrelevant or incorrect starting equations (such as $E = mc^2$ or $E = h\lambda$) could not be awarded credit.
- (iii) Most candidates who calculated a photon energy in (b)(ii) were able to make a correct deduction about emission from the two metals that was consistent with their photon energy.

Question 11

- (a) There was a wide variety of performance in this question. As ever, it is important that candidates answer the question asked. There were several detailed explanations of magnetic resonance imaging that were irrelevant to the question. It is crucial that candidates take care with their wording and use technical terminology accurately.

For this question, the fundamental principle that candidates had to explain in order to be awarded credit is that CT scans divide up the object being scanned into slices. Each slice is scanned in turn, many times, in order to produce a 2-dimensional image. Finally, this process is repeated for multiple slices and the 2-dimensional images are combined together to build up a 3-dimensional image of the whole structure. Candidates who omitted discussion of 'slices' or 'sections' of the

body were not able to score credit. Some answers were confused (e.g. talking about the images being 'sliced') and could not be awarded credit.

Other common pitfalls were to omit reference to X-rays as being the radiation used for scanning and to confuse when the image is 2-dimensional and when it is 3-dimensional. Candidates who simply try to memorise and reproduce previous mark schemes, without developing any real understanding of what they are trying to describe, often make these mistakes.

- (b)(i) In both parts of (b), a common mistake was to give responses that merely restated the question. In describing the need to compile many 2-dimensional images together, many candidates simply stated that this was 'not possible without fast computers with large memories'. The idea that this compilation required large numbers of calculations was often missing.
- (ii) Many responses restated that more exposure to X-rays was needed, without explaining this by reference to the many images taken in CT scans.

Question 12

- (a) A significant minority of candidates answered a question asking for the definition of decay constant rather than the meaning of radioactive decay. Of those who did address the question that was asked, crucial parts of the answer were sometimes missing. Some answers did not contain reference to 'emission' or 'unstable'. Some described the particles emitted as themselves being radioactive. Candidates who knew their basic 'bookwork' were able to be awarded full credit.
- (b)(i) The labelling of the lines on the graph was generally done well, and many candidates were able to score full credit. There were a few instances of candidates contradicting themselves by labelling the same line with two letters.
- (ii) Most candidates knew how to calculate decay constant from half-life. Some candidates rounded their answer to 2 significant figures, even though it was obtained entirely from 3 significant figure data.
- (c) Some candidates were able to deduce that the consequence of nuclide F having a much larger decay constant than nuclide E is that it has a much shorter half-life (than E). The comparison here was essential in order to be able to answer the question properly. Only a small number of candidates were able to go on to explain the consequence of this comparison, that nuclei of nuclide F decay almost as soon as they are formed.

Many candidates asserted that nuclei of F decay 'faster' than those of nuclide E. The answers of a large number of candidates suggested that they did not realise that nuclei of F do not exist until a nucleus of E has decayed.

PHYSICS

Paper 9702/43 A Level Structured Questions

Key messages

- It is important that candidates use technical language accurately. In this paper, the words that candidates often confused were 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. There were several questions on this paper where a significant number of candidates gave answers to questions that were not asked, but have been asked in recent past papers. Candidates should be advised not to rely heavily on memorising previous mark schemes.

General comments

In general terms, candidates scored well on traditional questions involving 'bookwork' and not as well on questions requiring application of knowledge. Working was nearly always shown, which is encouraging, and the use of English was very 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 may depend on the explanation.

Comments on specific questions

Question 1

- (a) This statement of Newton's law of gravitation was well-known. A significant number of candidates did not mention point masses.
- (b)(i) Only the strongest candidates were able to answer this question correctly. Many candidates incorrectly thought that the planets were in equilibrium, either because the speed was constant, the forces on each planet and the star were equal and opposite, or because the gravitational and centripetal forces were equal. It was also quite common for a candidate to state that the planets were not in equilibrium because the radii, masses or forces were different.
- (ii) 1. This was generally answered correctly by most candidates.
2. Few candidates gained full credit here by demonstrating that they had used the data for more than one planet. Most candidates used data for only the first planet in the list. Some candidates did not look at the column headings carefully and squared the data for T^2 , hence leading to an incorrect answer for the mass.

Question 2

- (a) (i) Some responses stated that a was directly proportional to y and a was in the opposite direction to y , but without explaining how the graph showed this. Some omitted the phrase 'through the origin'.
- (ii) This calculation was completed well. There were a few power-of-ten errors caused by not converting the displacement from mm into m. Some of the least able candidates started with the incorrect formula $a = \omega x$, which could not be awarded credit.
- (b) (i) Candidates who had encountered this idea before found it easy to gain full credit. The displacement in simple harmonic motion has both positive and negative values. If a position is being stated, it is important to be precise with terminology: 'maximum displacement/amplitude' could not be awarded credit as there was no direction specified.
- (ii) Common errors were to use an acceleration of 4.5 ms^{-2} as this was the end of the line on the graph, or 5.0 ms^{-2} as this was the maximum value on the acceleration axis.

Question 3

- (a) (i) The weakest candidates often gave answers in terms of the first law of thermodynamics (internal energy is the work done plus heat supplied). Weak candidates who avoided doing this tended to answer in terms of the sum of kinetic energy and potential energy of the system, but without specifying that they meant the energies of the molecules.
- (ii) Candidates were either quite familiar with this idea and knew how to relate the change in internal energy to the change in thermodynamic temperature, or they were not sure at all and again made reference to the first law of thermodynamics.
- (b) A simple approach was to use $pV = NkT$ and substitute. Most candidates chose to use $pV = nRT$ to find n and then used $N = nN_A$ to find N . Some candidates made power-of-ten errors in converting the volume or thought they had reached the final answer when they had found n , the number of moles.

Question 4

- (a) This question was well answered, and a variety of correct answers were given.
- (b) It was quite common for weaker candidates to give long-winded and unnecessary descriptions either of how an ultrasound transducer works or general descriptions of the medical diagnoses possible using ultrasound. Candidates should be reminded to read the question carefully and focus their answers on the specific question being asked.

Common mistakes included:

- not mentioning that the ultrasound is sent into the body as pulses,
- not stating that the time delay between and the relative amplitudes of the transmitted and reflected pulses gives information about the depth and nature of the **boundary** between the body's structures, not the structures themselves,
- not adequately explaining the purpose of the coupling gel.

Question 5

- (a) (i) This was well answered. Candidates need to be specific when referring to the direction of rotation, e.g. 'the same direction as the rotation of the Earth'. Clockwise/anticlockwise could not be awarded credit as these depend on where the observer is.
- (ii) This question asked for the position of the satellite. Some candidates gave 'stationary' but this is a description of the velocity relative to the Earth rather than the position.
- (iii) Candidates either needed to recall a frequency here or use their knowledge of the electromagnetic spectrum. Some weaker candidates calculated the frequency associated with a time period of 1 day, i.e. confused the communication frequency with the orbital frequency.

- (b)(i) Many candidates arrived at a correct signal power having used $195 = 10 \lg(3000/P)$. Weaker candidates often found a very large signal power having incorrectly used $195 = 10 \lg(P/3000)$.
- (ii) Explaining the need for different frequencies for the up-link and down-link was less well done. A common misconception amongst weaker candidates was that the signal's frequency rather than its power became attenuated during propagation. Stronger candidates grasped the concept that the attenuated up-link signal would be swamped by the amplified down-link signal if the frequencies were the same, but weaker candidates' responses often had a lack of clarity over which signal was being swamped. Unclear phrases such 'swamping between' and 'swamping with' were quite common.

Question 6

- (a) The majority of candidates knew this definition.
- (b) Correct answers were common. Some candidates made the task harder than it needed to be by first calculating V using $V = E \times d$ and then using $Q = V \times 4\pi\epsilon_0 d$. Some candidates made arithmetic mistakes or forgot to convert centimetres to metres. Weaker candidates who had incorrectly explained field strength tended to use $Q = E \times 4\pi\epsilon_0 r$ to calculate a value for Q .
- (c) Many candidates did not give answers in terms of Q . Answers of 4.5×10^{-7} without a unit were quite common. The weakest candidates tended to give an answer of 6.0×10^{-7} , not having subtracted Q .

Question 7

- (a) Candidates found it difficult to give a definition that applies to this specific situation. They often understood the definition of capacitance, but the question was asking for the definition as specifically applied to the parallel plate capacitor, so more detail was needed. There was some confusion between a parallel plate capacitor and capacitors connected in parallel.
- (b)(i) Most candidates answered this correctly.
- (ii) Many candidates found it difficult to understand how the circuit functions and could not gain credit. A common incorrect answer was to divide the answer in (b)(i) by 2 rather than 50.
- (iii) Many candidates realised that they needed to divide their previous answer by 120.
- (c) If a second capacitor of equal capacitance is placed in series with the first, then the capacitance is halved. Therefore, the current is halved. Many candidates said that the two quantities decreased, but it was possible to be more specific than this. If values are given in the question, then candidates should be encouraged to make full use of them.

Question 8

- (a) The most common creditworthy description of negative feedback was of the form 'negative feedback is when some of the output voltage is fed back to the inverting input of the amplifier'. Weaker candidates would tend not to state which input the voltage was fed back into.
- Some of the weakest candidates tended to write down everything they could remember about op-amps and quite often contradicted themselves. Some weaker candidates also tended to get things backwards, e.g. 'negative feedback increases the gain and reduces the bandwidth'. Some candidates were not clear about the difference between open-loop and closed-loop gain and gave 'reduced open-loop gain' as an incorrect answer.
- (b)(i) Candidates generally calculated the gain correctly, although a significant number worked out the gain (correctly) as -12 and then wrote 12 on the answer line. This is an inverting amplifier circuit and the gain should be negative.
- (ii) This was usually answered correctly. A common mistake was to forget that the power supply to the op-amp was 6 V and that the output cannot be greater than this value.

- (iii) Many candidates stated that one of the resistors should be swapped for a light-dependent resistor (LDR) but did not state which resistor should be replaced.

Question 9

- (a) Candidates generally realised that there was a force on the wire and usually worked it out as being upwards. Many candidates did not read the question correctly and gave the force on the wire rather than the force on the magnets.
- (b) (i) This calculation was straightforward, and the majority could recall that $F = BIL \sin \theta$. A few weaker candidates overlooked that the flux density was in mT and their final answer was incorrect by a factor of 10^{-3} .
- (ii) Most candidates were correct. A common incorrect answer was $1.85 \times 10^{-3} \text{ N}$ as candidates divided by $\sin 60^\circ$ but forgot to multiply by $\sin 60^\circ$ as well.
- (c) A few candidates did not draw an alternating waveform. Whatever waveform candidates drew, it was common for weaker candidates to draw less than two cycles, and to omit to put any values on the axes. Some of the stronger candidates could have improved their answers by taking more care when sketching their waveforms and ensuring that the waveform does not have different positive and negative amplitudes or a changing time period.

Question 10

- (a) Most candidates gained credit for this definition.
- (b) This question proved to be difficult. Many candidates could state Lenz's law but found it difficult to assemble a reasoned argument. Some candidates gave an answer formed around the idea that the ring jumps upwards because 'the e.m.f. in the ring opposes the e.m.f. in the coil'. Some of the stronger candidates did understand the notion of two opposing magnetic fields resulting in an upward force on the ring, but were unable to come up with a convincing argument in support of this. The strongest candidates wrote well-reasoned explanations and were awarded full credit.

Question 11

- (a) (i) Most candidates were awarded credit, although the word energy was sometimes missed out.
- (ii) Candidates found this question difficult. The question was asking for evidence and the answers of many candidates were not focused on evidence.
- (b) Some weak candidates answered in terms of the electrons in the photoelectric effect, and used phrases such as 'work function' and 'threshold frequency' that were not relevant to the question. Some candidates did not understand the one-to-one relationship between a photon and an electron, and instead constructed arguments based on the absorbed photons making the material warmer and this making the electrons more energetic. It would be helpful to emphasise further the idea of the one-to-one interaction to these candidates. Other weaker candidates tended to state that electrons absorbed energy directly from the incident light without using photons in the explanation, and had electrons 'jumping over' the forbidden band without a sense of which direction they were jumping in.

As with previous explanations, strong candidates could provide a clear explanation.

Question 12

- (a) (i) Most candidates understood the question. Some candidates gave answers to 1 significant figure when the data were given to 2 significant figures.
- (ii) The effect of passing through more than one material was not well understood, and some candidates incorrectly added, subtracted or occasionally divided the exponential decay terms.

- (b)(i) The weakest candidates thought that contrast had something to do with image clarity or sharpness. Whilst most candidates knew it had something to do with image brightness and darkness, many found it difficult to express this. Only a few stated it was the difference in the degree of blackening between structures.
- (ii) Weaker candidates tended to ignore the values they had just calculated, and instead referred to the absorption coefficients rather than the relative differences in transmitted intensity between soft tissue and a combination of bone and soft tissue.

Question 13

- (a) Candidates found it difficult to give a complete answer. Radioactivity is a nuclear process. Some answers contained descriptions of fission or did not mention that particles/radiation was emitted. The key words 'unstable' and 'spontaneous' were often missing.
- (b)(i) Some weaker candidates incorrectly calculated the activity as the gradient of a line drawn from the origin to the curve at $t = 14$ minutes. The easiest way to answer the question was to draw a tangent at 14 minutes and then to find the activity as the gradient of the tangent. Another approach was to find the half-life and work out the activity from it.
- (ii) Most candidates gained credit for this question.

PHYSICS

Paper 9702/51 Planning, Analysis and Evaluation
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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**, the methods that candidates described often did not contain enough detail and did not mention the appropriate measurements. 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 many unworkable set-ups shown in diagrams and a few candidates chose the wrong independent and dependent variables. A large number of candidates did well on the analysis section. Many candidates did not provide enough additional detail. For example, a statement such as 'the experiment was repeated the results averaged' is too generic and does not contain enough detail. It is essential for candidates to have experienced practical work in preparation for answering this paper.

In **Question 2**, the initial algebraic task was difficult and this led to problems in later parts of the question for some candidates. 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 significant 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. At all stages, candidates must keep in mind the unit of each answer. Candidates should set out their working in a logical and readable manner.

There was a significant minority of candidates who omitted the last part of the paper. This could be due to the difficulty of the equation in **Question 2** which was required for the analysis in the final parts of the paper.

Comments on specific questions

Question 1

Most 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 distance r needed to remain constant, although some candidates identified r as the independent variable. Some 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 set-up of the experiment and should include all the equipment that is to be used. In this question, candidates needed to show labelled spheres with sphere T clearly attached to a support, e.g. a stand and clamp or hook from the (labelled) ceiling, and sphere S placed on a top-pan balance. There should also be clear indications of distance(s) that are to be measured. There were a significant number of diagrams that were unworkable such as sphere T incorrectly suspended, sphere S being clamped, sphere S not in contact with the balance, or both spheres placed horizontally.

To obtain the value of F , readings from the top-pan balance are required. Many candidates did not indicate there was a mass/force/reading difference to be taken. Some candidates mentioned to tare the balance after placing sphere S on it. Credit for additional detail was available for converting the change in mass reading to force. The statement $F = mg$ could only be awarded credit if m (change in mass) and g (acceleration of free fall) were defined. Candidates should be encouraged to define symbols in any equation that is used.

To obtain the value of the e.m.f. V of the power source, a voltmeter is required placed in parallel with the power source. This could be awarded based on a correct electrical circuit diagram. Very few candidates were awarded credit as the majority of candidates either drew the connected sphere as part of a complete circuit (in effect measuring the p.d. across sphere T) or put the voltmeter in series.

Most candidates described a measurement of distance r between the spheres with a ruler. Stronger candidates were often awarded credit on the basis of a diagram showing a ruler placed adjacent to distance r in the diagram with r clearly indicated. A mark for additional detail was available for explaining how the distance r can be obtained from the measured readings. A further mark could then be obtained for the measurement of the diameter (hence radius) of the spheres, although this had to be relevant to the measurement of r . Some candidates described very well the checking of the spheres to ensure that they were the same diameter and then measuring from the top of one to the top of the other. Others described measuring the distance between the spheres and adding the radii.

Credit was available for the analysis of data. The majority of candidates selected the correct axes for the graph, but a small proportion of candidates incorrectly suggested plotting r on one of the axes. Candidates must explicitly state the quantities to be plotted on each axis either in the text or on drawn axes. A mark was available for explaining how the graph would confirm the suggested relationship. Candidates needed to use the words 'relationship is valid if', the word 'straight' to describe the line and also state 'passing through the origin'.

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. For example, insulating gloves are worn to avoid electric shock. Other good safety precautions included the use of shrouded leads or the avoidance of bare connections owing to the high voltages used.

Candidates must be specific when repeating readings and averaging. The relevant quantities need to be stated. In this experiment, candidates needed to state that for each value of V , the experiment would be repeated and the average F determined.

Other creditworthy additional detail included realising that an insulator is required between the charged spheres and the balance/stand and clamp, discharging the spheres by earthing, giving a method to ensure the charge on S is constant and preventing draughts from moving sphere T.

Question 2

- (a) Candidates who were mathematically confident were able to work through the algebra and achieve credit. A significant number of candidates arrived at wrong and sometimes complicated expressions for both the gradient and y-intercept. A few candidates omitted the minus sign in the y-intercept.
- (b) Completing the table was straightforward. Some candidates did not consider the appropriate number of significant figures. The first four readings in the s column were to two significant figures while the last two readings were to three significant figures. The calculated values of the $1/s^2$ column could be given to two or three significant figures for the first four readings and three or four significant figures for the last two 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 significant 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 the 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. 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 $y = mx + c$. 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) Many candidates found this part difficult. It was essential that the gradient and y-intercept were used. Candidates who used the gradient and y-intercept correctly and gave their answers to an appropriate number of significant figures were given credit. The determination of D was generally achieved by those candidates who used the correct formulae in (a). The determination of N required correct logical working with numbers substituted for each quantity. In addition, the correct power of ten and units were also required. Some stronger candidates correctly used a combination of the y-intercept and gradient to determine N . Candidates should be encouraged to consider both the powers of ten and the units used on the plotted graph.
- (ii) Many candidates found this part difficult and a significant minority of candidates omitted it. Candidates who fully understood the treatment of uncertainties and, in particular, how the theory is applied to square root and squared terms were able to gain credit. Stronger candidates clearly presented their working in a readable, logical order. Some candidates attempted to find the percentage uncertainty by maximum/minimum methods. Again, stronger candidates who demonstrated clearly their method gained credit.

PHYSICS

Paper 9702/52 Planning, Analysis and Evaluation
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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**, the methods that candidates described often did not contain enough detail and did not mention the appropriate measurements. 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. A few candidates chose the wrong independent and dependent variable. Many candidates did well on the analysis section although a significant number of candidates stated that the straight line would pass through the origin. 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**, the initial algebraic task was difficult and this led to problems in later parts of the question for some candidates. Candidates should be familiar with completing a results table for quantities and their uncertainty and with drawing a graph to find the gradient. For a significant 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 there were wrong readings of coordinates for the gradient.

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. At all stages, candidates must keep in mind the unit of each answer. Candidates should set out their working in a logical and readable manner.

There was a significant minority of candidates who omitted the last part of the paper. This could be due to the difficulty of the equation in **Question 2** which was required for the analysis in the final parts of the paper.

Comments on specific questions

Question 1

Candidates should be advised to read the question carefully before starting their answer. Most candidates correctly identified the independent and dependent variables. Candidates should be encouraged then to consider the control of variables and which quantities need to be kept constant. Some 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 set-up of the experiment and should include all the equipment that is to be used. In this question, candidates needed to show a named light source attached to a support, e.g. a stand and clamp, with the diagram showing a workable arrangement. Some candidates incorrectly added either two slits or a diffraction grating.

Candidates also needed to give the method of changing the wavelength and of measuring the quantities h and λ . Appropriate measuring instruments and techniques must be stated. Stronger candidates clearly indicated the use of filters when using a white light source or suggested using lasers of different colours to change the wavelength of the incident light.

To obtain the value of the wavelength λ of the incident light, a large number of candidates suggested carrying out an experiment using two slits or a diffraction grating. Having stated an appropriate experiment, candidates could then gain credit for stating an equation showing how the wavelength λ of the incident light could be determined. Candidates should be encouraged to clearly define the symbols that are used. Candidates who used filters could gain credit for suggesting recording the value from the filter, although it would have been better to provide a more detailed method.

Most candidates correctly suggested measurement of distance h with a ruler. Some candidates were awarded credit on the basis of a clearly labelled diagram which included the metre rule adjacent to the distance h which was clearly indicated. Some candidates were awarded credit for explaining how the distance h was found accurately by measuring the distance to the top and bottom of the maxima and determining the mean value of h .

Credit was available for the analysis of data. The majority of candidates selected the correct axes for the graph, usually stating that h was plotted on the y -axis and λ on the x -axis. Candidates must explicitly state the quantities to be plotted on each axis, either in the text or on drawn axes; simply writing the equation of a straight line underneath the given expression was not sufficient to gain credit. Candidates also needed to explain how to find the values of the constants d and B using the graph. The constants must be the subject of the expression used. It was expected that d would be expressed in terms of the gradient and B in terms of the y -intercept. Candidates who reversed the axes by plotting λ on the y -axis and h on the x -axis could still gain full credit, although the determination of B was more difficult. There was an additional detail mark for explaining how the graph would confirm the suggested relationship. Candidates are expected to state the words 'relationship is valid if' and the word 'straight' to describe the line. Some candidates incorrectly stated that the line passed through the origin and could not be awarded credit since there had to be a y -intercept.

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 which required a clearly reasoned precaution relevant to the experiment. A reason must be given as to why the safety precaution is selected. In this experiment, many candidates suggested the use of lasers or intense light sources, and could receive credit for a safety precaution to prevent damage to the eyes from the light. Candidates need to give sufficient detail; 'wear goggles' on its own was not accepted since it was not clear whether the goggles were protecting the eyes from intense light or moving objects.

A further mark for additional detail was awarded to candidates who suggested the use of an intense light source. Candidates needed to explicitly state this requirement. Candidates who decided to use a laser could have been awarded credit here for explaining why a laser was being used. The mark could also be awarded for the use of a collimated light source.

Other creditworthy additional detail included explaining how the zero order maximum was obtained and thus the given order was measured, performing the experiment in a dark room and cleaning the surface of the CD.

Question 2

- (a) Candidates who were mathematically confident were able to work through the algebra and achieve credit for determining an expression for the gradient. A significant number of candidates arrived at wrong and sometimes complicated expressions. A few candidates were confused by the minus sign. A common error was to omit the '1'.
- (b) Completing the table was straightforward. Some candidates did not consider the appropriate number of significant figures. Since R was given to two significant figures, the calculated readings of the nR column could be given to two or three significant figures.

Most candidates found the uncertainties correctly. A number of candidates incorrectly determined the absolute uncertainty in nR , often writing incorrectly that the uncertainty for $n = 2$ was 1 or 1.0 instead of 0.9 or 0.94.

- (c) (i) The majority of the stronger candidates were awarded full credit. The points and error bars were straightforward to plot. A significant number of candidates drew large 'blobs' for the plotted points which could not be given credit. Candidates need to take greater care over the accuracy of the error bars and ensure that the 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. For this set of data, the line of best fit should not have passed through both the highest and lowest points.

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.
- (d) (i) Many candidates found this part difficult. It was essential that the gradient was used. Candidates who used the gradient and gave their answers to an appropriate number of significant figures were given credit. The determination of C was generally achieved by those candidates who had a correct expression in (a). Credit was also available for the correct power of ten and correct units for C . Candidates should be encouraged to consider both the powers of ten and the units used on the plotted graph.
- (ii) Many candidates who fully understood the treatment of uncertainties realised that the percentage uncertainty in C was equal to the percentage uncertainty in the gradient. Stronger candidates clearly presented their working in a readable, logical order. Some candidates attempted to find the percentage uncertainty by determining the maximum or minimum value of C , and candidates who clearly demonstrated this method gained credit.
- (e) Many candidates found this part difficult and a significant minority of candidates omitted it. Again, stronger candidates clearly presented their working in a readable, logical order. Common mistakes were power-of-ten errors or not correctly interpreting the 90% value for V/E .

Stronger candidates who realised that the fractional uncertainty in K was the same as the fractional uncertainty in C often gained credit. Some candidates attempted to find the absolute uncertainty by maximum/minimum methods. Again, stronger candidates who demonstrated clearly their method gained credit.

PHYSICS

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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**, the methods that candidates described often did not contain enough detail and did not mention the appropriate measurements. 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 many unworkable set-ups shown in diagrams and a few candidates chose the wrong independent and dependent variables. A large number of candidates did well on the analysis section. Many candidates did not provide enough additional detail. For example, a statement such as 'the experiment was repeated the results averaged' is too generic and does not contain enough detail. It is essential for candidates to have experienced practical work in preparation for answering this paper.

In **Question 2**, the initial algebraic task was difficult and this led to problems in later parts of the question for some candidates. 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 significant 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. At all stages, candidates must keep in mind the unit of each answer. Candidates should set out their working in a logical and readable manner.

There was a significant minority of candidates who omitted the last part of the paper. This could be due to the difficulty of the equation in **Question 2** which was required for the analysis in the final parts of the paper.

Comments on specific questions

Question 1

Most 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 distance r needed to remain constant, although some candidates identified r as the independent variable. Some 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 set-up of the experiment and should include all the equipment that is to be used. In this question, candidates needed to show labelled spheres with sphere T clearly attached to a support, e.g. a stand and clamp or hook from the (labelled) ceiling, and sphere S placed on a top-pan balance. There should also be clear indications of distance(s) that are to be measured. There were a significant number of diagrams that were unworkable such as sphere T incorrectly suspended, sphere S being clamped, sphere S not in contact with the balance, or both spheres placed horizontally.

To obtain the value of F , readings from the top-pan balance are required. Many candidates did not indicate there was a mass/force/reading difference to be taken. Some candidates mentioned to tare the balance after placing sphere S on it. Credit for additional detail was available for converting the change in mass reading to force. The statement $F = mg$ could only be awarded credit if m (change in mass) and g (acceleration of free fall) were defined. Candidates should be encouraged to define symbols in any equation that is used.

To obtain the value of the e.m.f. V of the power source, a voltmeter is required placed in parallel with the power source. This could be awarded based on a correct electrical circuit diagram. Very few candidates were awarded credit as the majority of candidates either drew the connected sphere as part of a complete circuit (in effect measuring the p.d. across sphere T) or put the voltmeter in series.

Most candidates described a measurement of distance r between the spheres with a ruler. Stronger candidates were often awarded credit on the basis of a diagram showing a ruler placed adjacent to distance r in the diagram with r clearly indicated. A mark for additional detail was available for explaining how the distance r can be obtained from the measured readings. A further mark could then be obtained for the measurement of the diameter (hence radius) of the spheres, although this had to be relevant to the measurement of r . Some candidates described very well the checking of the spheres to ensure that they were the same diameter and then measuring from the top of one to the top of the other. Others described measuring the distance between the spheres and adding the radii.

Credit was available for the analysis of data. The majority of candidates selected the correct axes for the graph, but a small proportion of candidates incorrectly suggested plotting r on one of the axes. Candidates must explicitly state the quantities to be plotted on each axis either in the text or on drawn axes. A mark was available for explaining how the graph would confirm the suggested relationship. Candidates needed to use the words 'relationship is valid if', the word 'straight' to describe the line and also state 'passing through the origin'.

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. For example, insulating gloves are worn to avoid electric shock. Other good safety precautions included the use of shrouded leads or the avoidance of bare connections owing to the high voltages used.

Candidates must be specific when repeating readings and averaging. The relevant quantities need to be stated. In this experiment, candidates needed to state that for each value of V , the experiment would be repeated and the average F determined.

Other creditworthy additional detail included realising that an insulator is required between the charged spheres and the balance/stand and clamp, discharging the spheres by earthing, giving a method to ensure the charge on S is constant and preventing draughts from moving sphere T.

Question 2

- (a) Candidates who were mathematically confident were able to work through the algebra and achieve credit. A significant number of candidates arrived at wrong and sometimes complicated expressions for both the gradient and y-intercept. A few candidates omitted the minus sign in the y-intercept.
- (b) Completing the table was straightforward. Some candidates did not consider the appropriate number of significant figures. The first four readings in the s column were to two significant figures while the last two readings were to three significant figures. The calculated values of the $1/s^2$ column could be given to two or three significant figures for the first four readings and three or four significant figures for the last two 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 significant 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 the 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. 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 $y = mx + c$. 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) Many candidates found this part difficult. It was essential that the gradient and y-intercept were used. Candidates who used the gradient and y-intercept correctly and gave their answers to an appropriate number of significant figures were given credit. The determination of D was generally achieved by those candidates who used the correct formulae in (a). The determination of N required correct logical working with numbers substituted for each quantity. In addition, the correct power of ten and units were also required. Some stronger candidates correctly used a combination of the y-intercept and gradient to determine N . Candidates should be encouraged to consider both the powers of ten and the units used on the plotted graph.
- (ii) Many candidates found this part difficult and a significant minority of candidates omitted it. Candidates who fully understood the treatment of uncertainties and, in particular, how the theory is applied to square root and squared terms were able to gain credit. Stronger candidates clearly presented their working in a readable, logical order. Some candidates attempted to find the percentage uncertainty by maximum/minimum methods. Again, stronger candidates who demonstrated clearly their method gained credit.