

PHYSICS

Paper 9702/11
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	B	23	C
4	C	24	A
5	D	25	D
6	C	26	C
7	B	27	A
8	B	28	C
9	B	29	D
10	D	30	C
11	D	31	C
12	A	32	C
13	A	33	C
14	B	34	A
15	B	35	D
16	D	36	B
17	A	37	B
18	B	38	D
19	B	39	B
20	A	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 11, 28, 29, 37 and 38** difficult, and they found **Questions 1, 7, 18, 22, 23 and 27** to be relatively easy.

Comments on specific questions

Question 5

This question was answered well by the able candidates, but many weaker candidates found it difficult to handle the uncertainties. The incorrect answers were all popular so it is possible that these candidates were guessing.

Question 6

Candidates generally knew that the direction was eastward, but found it more difficult to determine the angle of the direction.

Question 11

The key point of information given is that the collision is perfectly elastic. There is no need to use kinetic energy or momentum. The relative speed of approach is 6 cm s^{-1} , so the relative speed of separation must also be 6 cm s^{-1} . Sketching a quick diagram showing the directions in which the spheres move might help candidates to see that the final speed of sphere Y must be 8 cm s^{-1} , which is **D**.

Question 12

Diagram **A** is correct with all the arrows having increasing length as the depth of water increases. Diagram **C** cannot be correct as it has too little pressure at the side near the top, while **D** is incorrect because it has a constant pressure all the way down the side.

Question 24

This question is really recognising whether the wavelength and the example had similar sizes. Microwaves and a steel post could both have a magnitude of about 3 cm, so **A** is the correct answer. None of the other three are anywhere near to having the same size, so they will not be good examples of diffraction.

Question 28

Many candidates chose **A**, indicating that interference would be observed along the lines RS and XY. Along RS, the distances to P and Q are always the same, so there is no path difference and there can be no interference. Interference is only observed along XY.

Question 29

Use of a large gap width will decrease the amount of diffraction. Increasing the frequency will reduce the amount of diffraction, so the correct answer is **D**.

Question 36

When the switch is closed, the circuit resistance decreases, so both the current and the p.d. indicated by the voltmeter (across a fixed resistance) increase. The incorrect answer **D** was relatively common.

Question 37

Candidates needed to check each of the four equations carefully using Kirchhoff's second law. Of the equations given, only **B** results from a correct use of the equation around a closed 'loop'. None of the other equations is correct.

Question 38

One way to solve this problem is to use the idea of a potential divider. The potential at the point between resistors P and Q must be equal to the potential at the point between resistors R and S, and this implies that **D** is the correct relationship.

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Paper 9702/12
Multiple Choice

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

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 5, 6, 7, 32 and 37** difficult, and they found **Questions 2, 3, 26, 28 and 40** to be relatively easy.

Comments on specific questions

Question 5

Many candidates forgot to double the time for the pulse to travel to the reflector in order to find the total time. These candidates chose **A** instead of the correct answer **C**.

Question 6

This question can be answered using $s = ut + \frac{1}{2}at^2$ but it requires care to be taken over the signs. The initial velocity u of the sandbag is upwards, so this requires a negative sign if displacement downwards s is taken as positive, i.e. $s = -3.00 \times 5.00 + \frac{1}{2} \times 9.81 \times 5.00^2$.

Question 7

Many candidates chose **A**, but the area beneath the graph is less than on the original graph. The area represents the distance between the stations, so it must be the same for the second train.

Question 12

The cube would topple anticlockwise when released, so the couple needed to stop it turning must be clockwise. A large number of candidates chose **A**, so they determined the correct magnitude of the torque but not the correct direction.

Question 14

Candidates would find this type of question easier if they drew on their question papers. Here, a drawing of the two upwards forces from the beams at Y will be at 40° to the vertical. The equation to be solved for the single force F is then $2F \cos 40^\circ = 4.0 \times 10^4 \text{ N}$.

Question 24

The quickest way to answer this question is to note that the distance between two nodes is half a wavelength.

Question 32

The direction of the force on an electron is opposite to the direction of the field, so the field in this case decelerates the electron and the answer is **B**. Many candidates chose **C**, which has the correct magnitude but the wrong sign.

Question 33

When the wire widens, the drift speed of the electrons decreases to maintain a constant current. Candidates choosing **A** either made a mistake manipulating the equation or intuitively felt that the electrons would be slowed down in the narrow wire, when in fact the opposite is true.

Question 37

This question needs to be tackled from first principles. Using Kirchhoff's first law, the currents in the two R resistors must be 1.0 A and 1.5 A. Then, using Kirchhoff's second law, $12.0 = 1.0R + 1.5R + 4.0 \times 0.50$, and solving for the resistance R gives 4.0Ω . Stronger candidates were able to answer this correctly but many weaker candidates appeared to be guessing.

PHYSICS

Paper 9702/13
Multiple Choice

<i>Question Number</i>	<i>Key</i>	<i>Question Number</i>	<i>Key</i>
1	C	21	A
2	C	22	C
3	A	23	D
4	B	24	A
5	B	25	C
6	D	26	C
7	C	27	D
8	D	28	C
9	B	29	B
10	A	30	C
11	B	31	A
12	B	32	C
13	C	33	D
14	A	34	D
15	A	35	C
16	D	36	B
17	C	37	C
18	D	38	D
19	A	39	C
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 8, 18, 29, 35, 36 and 37** difficult, and they found **Questions 3, 17, 23, 39 and 40** to be relatively easy.

Comments on specific questions

Question 8

Many candidates thought that the contact force would still be equal to the weight of the man and chose **A**. This cannot be true because the man is accelerating downwards. There must be a resultant force downwards on the man, so **D** is correct.

Question 18

The only extra detail required is h . This becomes clear when expressions for potential and kinetic energy are written out.

Question 20

The question states that the sample follows the same curve when it contracts, so its behaviour between X and Y is elastic and not plastic. Stronger candidates were able to reason this correctly but weaker candidates often chose **C**.

Question 27

This question should require only recall, but weaker candidates often chose **B**. The frequencies of **A**, **B** and **C** are all lower than that of visible light so they cannot be ultraviolet.

Question 29

The slit spreads the light horizontally because it is narrow in the horizontal direction. This makes **B** the answer, but many candidates chose **C**. The grating is wide in the vertical direction so very little diffraction occurs in this direction.

Question 35

Many candidates chose **B**, so they correctly determined the reading for the forward direction but not the reverse direction. If the diode is reverse biased, there will be zero current in the circuit. This does not mean that there is zero reading on the voltmeter. With the voltmeter connected directly across the cell, it will record the full 3V of the cell.

Question 36

The answer to this question becomes more obvious if the diagram is sketched so that the two cells are beneath one another. When $R = r_1 - r_2$ the bottom two sections are identical and the p.d. across the resistance is balanced by the e.m.fs. There are also algebraic routes to this answer using Kirchhoff's second law.

Question 37

Two of the cells are providing an e.m.f. in one direction and the other in the opposite direction. This gives the circuit current as $E/3R$ so the p.d. between P and Q is $E - E/3$ ($= 2E/3$) which is **C**. Many candidates chose **B**.

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Paper 9702/21 AS Level Structured Questions
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Key messages

- Candidates should give clear calculations to numerical questions. The first step should be to state any appropriate symbol equation. It is important that the subject of the equation is clearly shown. The substitution of the data should be presented and then the final answer can be calculated. Candidates who methodically present their calculations in this way are often able to gain partial credit even when an error is made midway through their working.
- Definitions should be recalled 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. 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 check whether their numerical answers have a sensible order of magnitude. If the answer has an unrealistic value, they should quickly review their working to see if a simple error, such as a power-of-ten error, has been made.

General comments

There were plenty of opportunities on this paper for weaker candidates to demonstrate their knowledge. Some candidates had difficulty applying their knowledge to the context of some of the questions, such as in **Questions 1(b), 7(b) and 8(b)**. There were many good answers to **Question 2**.

Some candidates did not answer all parts of all questions, but there was no evidence that an adequately prepared candidate had insufficient time to complete the paper.

Comments on specific questions

Question 1

- (a) Most candidates were able to recall the base units of force, density and speed. Particular care needed to be taken with the powers of the base units when combining them to achieve the final answer.
- (b)(i) Candidates found it difficult to manipulate the given expression in order to calculate the drag force acting on the ball.
- (ii) Many candidates incorrectly assumed that the resultant force on the ball was equal either to the weight or to the drag force rather than to the difference between the weight and the drag force.
- (c) Many answers correctly stated that the acceleration decreases and that the final acceleration is zero. Candidates also needed to appreciate that the initial acceleration of the ball would be the acceleration of free fall. A common misconception was that the ball decelerates. Another misconception was that the ball initially has an increasing acceleration that is then followed by a decreasing acceleration.

Question 2

- (a) Candidates needed to either convert a speed of 100 km h^{-1} into units of m s^{-1} or convert a speed of 30 m s^{-1} into units of km h^{-1} . Most found this conversion to be straightforward.
- (b) The calculation of acceleration from a velocity-time graph is generally well understood. A small number of candidates calculated the acceleration of the wrong car.
- (c) The majority of candidates calculated the displacement of each car by using the area under the graph. A small minority determined the displacement using one or more equations of uniformly accelerated motion. Weaker candidates sometimes incorrectly calculated the displacement of a car simply by multiplying its final velocity by the time.
- (d) A significant number of candidates could calculate the 'extra' time, after $t = 12 \text{ s}$, needed for the cars to become level. Most did not then use the 'extra' time to calculate the actual time.

Question 3

- (a) (i) Many candidates knew that energy is transferred along a progressive wave and that energy is not transferred along a stationary wave.
- (ii) Only the stronger candidates were able to compare the phase difference between adjacent vibrating particles in a stationary wave and in a progressive wave. A common misconception is that two adjacent particles in a stationary wave have a phase difference of 180° .
- (b) (i) Many statements of what is meant by an antinode were incorrect. It was often stated that antinodes are positions of maximum displacement rather than positions of maximum amplitude.
- (ii) The distance between a node and an adjacent antinode was often calculated correctly.
- (iii) 1. The wavelength of the sound wave was usually calculated correctly from the information provided in the diagram of the tube. Sometimes the wavelength was incorrectly assumed to be the distance between two adjacent antinodes.
- 2. This part of the question was generally well answered, although some of the weakest candidates were not able to recall that the speed of a wave is equal to its frequency multiplied by its wavelength.
- (iv) The vast majority of candidates did not understand how to determine the fundamental frequency of a stationary wave in a given length of tube that is open at both ends. A common misconception is that the fundamental wavelength is equal to the length of the tube.

Question 4

- (a) There were many correct definitions of strain. When giving the definition, it is insufficient to refer to just 'length' instead of to 'original length'.
- (b) (i) This part of the question was generally well answered.
- (ii) There were many correct calculations of the minimum area from the maximum stress. Sometimes a power-of-ten error was made when the units of the force were not converted from kN to N.

Question 5

- (a) Many candidates were able to state the correct equation by applying Kirchhoff's first law to one of the two junctions in the circuit diagram.
- (b) The majority of the candidates found it difficult to apply Kirchhoff's second law to a loop of the circuit diagram. On most occasions, the final equation contained at least one incorrect term.
- (c) This question was difficult and only a small minority of answers were correct. Candidates found it difficult to apply Kirchhoff's second law to a loop of the circuit diagram in order to obtain an equation where all the terms have the correct sign.

Question 6

- (a) A precise definition of electric field strength was needed. It was insufficient to refer to just 'force per unit charge' without stating that the charge is a positive charge.
- (b)(i) The final speed of the particle was usually calculated correctly.
- (ii) The increase in the kinetic energy of the charged particle is equal to the work done by the electric field to move the particle between the plates. More able candidates understood this and were able to write down the value of the work done directly without performing a calculation. Weaker candidates often attempted an elaborate calculation and perhaps overlooked that they had been asked to state, not calculate, the work done and that the question was worth only one mark.
- (iii) Candidates who were able to recall the relevant formula for the work done by a force usually went on to give a fully correct answer.
- (iv) This part of the question was straightforward for candidates who were able to recall the appropriate equations for a charge in a uniform electric field. A significant number of candidates did not appear to have learnt the relevant equations or else inappropriately used the formula for the potential due to a point charge from the formulae sheet.
- (v) Although there were many correct answers, a significant proportion of candidates drew an incorrect curved graph line instead of a straight one. Those candidates were possibly thinking of a graph of speed against distance rather than kinetic energy against distance.

Question 7

- (a) Only a small minority of candidates were able to define the ohm. Many simply stated that it was the unit of resistance or that it was the ratio of potential difference to current. It is important that candidates appreciate that a unit is defined in terms of other units and not in terms of quantities.
- (b)(i) More able candidates were usually awarded full credit. Candidates of average ability sometimes obtained partial credit for recalling the relevant symbol equation, but then found it difficult to apply it to the ratio calculation.
- (ii) A significant proportion of candidates did not attempt this part of the question. Only the most able candidates realised that the filament wire has a larger resistance than, but the same current as, the connecting wires.
- (iii) The resistance of the filament wire was often calculated correctly from the power dissipated. Only a small number of candidates then went on to use that resistance to calculate the total resistance of the connecting wires.
- (iv) A precise and methodical explanation was required. It was insufficient to refer to a resistance without clarifying whether this was the resistance of the filament wire or the resistance of the connecting wires. A common misconception was that the resistance of the filament wire remains constant or increases when the current in it decreases.

Question 8

- (a) The syllabus requires that candidates should be able to describe a neutron in terms of a simple quark model. A significant proportion of candidates made no attempt to answer this part of the question. More able candidates had little difficulty recalling the quark composition of a neutron and the charge of each of its quarks.
- (b) Most candidates stated the charge values with units of C, although a small number expressed the charges in terms of the elementary charge. Some candidates incorrectly thought an antineutrino was charged. Mass values were usually given with units of kg, although a small number expressed the masses in terms of the unified atomic mass unit.

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Paper 9702/22 AS Level Structured Questions
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Key messages

- Candidates should give clear calculations to numerical questions. The first step should be to state any appropriate symbol equation. It is important that the subject of the equation is clearly shown. The substitution of the data should be presented and then the final answer can be calculated. Candidates who methodically present their calculations in this way are often able to gain partial credit even when an error is made midway through their working.
- Definitions should be recalled 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. 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 check whether their numerical answers have a sensible order of magnitude. If the answer has an unrealistic value, they should quickly review their working to see if a simple error, such as a power-of-ten error, has been made.

General comments

Most candidates were able to recall the basic formulae used in the numerical calculations on this paper. The presentation of calculations is generally improving. It is important that these are confined to the correct calculation space on the paper. It can sometimes be difficult to follow calculations that overspill onto other pages of the paper. Sometimes candidates found it difficult to apply their knowledge. Examples of applications that candidates found challenging were in **Questions 2(b)(iii), 3(e)(ii) and 7(d)**. Many weaker candidates found the algebraic manipulation required in **Question 6** particularly difficult.

Comments on specific questions

Question 1

- (a) (i) The majority of candidates correctly identified the micrometer screw gauge as a suitable measuring instrument. The most commonly stated incorrect instrument was vernier calipers.
- (ii) Most candidates realised that random errors may be reduced by taking repeat measurements and then averaging. It was important to state that these repeat measurements should be taken at different places on the wire. A common misconception is that random errors are reduced by checking the zero error or calibration of the instrument.
- (b) (i) The majority of calculations were correct. A small number of candidates made a power-of-ten error due to not converting the units of the diameter from mm to m.
- (ii) Most candidates were able to convert the absolute uncertainties of the measurements into percentage uncertainties. A significant minority of candidates made mistakes when combining the percentage uncertainties of the measurements to obtain the percentage uncertainty of the stress. A common mistake was to forget that the percentage error in the diameter needed to be doubled.

- (iii) The majority of candidates knew how to calculate the absolute uncertainty of the stress. However, many expressed their answer to an inappropriate number of significant figures.

Question 2

- (a) Although there were many correct definitions given, sometimes key words were omitted. For instance, it is insufficient to define the moment of a force as being 'the product of a force and the distance of the line of action of the force to a point' as this does not refer to the perpendicular distance. Weaker candidates incorrectly defined it as being 'the turning effect of a force' or else confused moment with momentum.
- (b)(i) Most answers were correct. The most common incorrect answer was $1.2r$.
- (ii) The majority of candidates were challenged by this part of the question. Many found it difficult to determine the correct algebraic expression for the anticlockwise moment produced by the force of magnitude 6.0 N . The expression often contained $\cos\theta$ instead of $\sin\theta$ or contained r instead of $r/2$. Those that could determine the correct expression were usually able to go on and complete the calculation correctly.
- (iii) Many candidates found this part difficult. The previous parts of the question were related to rotational equilibrium whereas this part was concerned with translational equilibrium. Some candidates did an elaborate calculation. Candidates could have realised that this wasn't needed because the question was worth only one mark, and careful reading of the question shows that a statement, rather than a calculation, is all that was needed.

Question 3

- (a) Most candidates correctly used the hydrostatic pressure formula to determine the pressure difference. Sometimes a power-of-ten error was made when the lengths of the sides of the cube were not converted from units of cm to m. Another common mistake was to calculate the pressure on the bottom face of the cube by dividing the weight of the tube by the area of the face.
- (b) This part of the question was effective at differentiating between strong and weak candidates. In 'show that' questions, the marks are awarded for the calculation as well as the final answer. It is important to write down all the steps of the calculation leading up to the answer.
- (c) Candidates needed to appreciate that there are three forces acting on the cube: the upthrust, the weight and the force exerted by the spring. The most common errors were to assume that the force exerted by the spring was equal to the upthrust or to the weight.
- (d) Most candidates correctly attempted to use Hooke's law to calculate the extension of the spring. Many then found it difficult to use their calculated extension to determine the initial height of the cube above the water surface. Some candidates drew helpful sketches on the diagrams to help them better visualise the problem.
- (e)(i) The candidates were well differentiated by this part of the question. Weaker candidates often ignored the upthrust and assumed that the resultant force on the cube in the water was equal to its weight. The candidates that made this assumption then calculated an acceleration of 9.81 m s^{-2} . Such candidates should have realised that it is unrealistic for the cube to have the acceleration of free fall when in water and this should have prompted them to re-check their calculation.
- (ii) Some answers appeared to confuse acceleration with velocity. Stronger candidates realised that the acceleration would decrease, but were often unable to give a supporting explanation for this. Candidates needed to explain that there is an increase in the viscous force acting on the cube. Many just referred to the pressure of the water increasing or made vague references to the upthrust. Others misunderstood the question and thought that they were being asked to explain what happens as the cube moves from air to water. A common mistake was to state that the acceleration of the cube would be constant because the upthrust is constant.

Question 4

- (a) Most candidates correctly stated that a stationary wave can be formed from two progressive waves of the same frequency travelling at the same speed. However, many did not mention that the waves should also travel in opposite directions and overlap. A common misconception is that the overlapping waves have a constant phase difference.
- (b)(i) This part of the question was usually answered correctly.
- (ii) Most candidates realised that the time taken was equal to half of the period of the wave, although a common error was to equate the time taken with a quarter of the period.
- (iii) Many candidates need to improve their understanding of the phase difference between different particles in a stationary wave. Very few realised that the correct phase difference was 180° . A significant proportion wrongly stated that it was 135° , possibly because they had confused the stationary wave with a progressive wave. A few did not read the question carefully and did not include a unit in their answer.
- (iv) The majority of answers were correct, although a common error was to confuse the wavelength of the wave with the total distance between the two fixed points.

Question 5

- (a) A precise definition was needed. Some candidates incorrectly stated that a coulomb is current multiplied by time. Such candidates need to appreciate that units are defined in terms of other units and not in terms of quantities. The weakest candidates simply said that a coulomb is the unit of charge.
- (b)(i) Most candidates could recall the relevant formulae. For 'show that' questions, it is particularly important that candidates remember to explicitly state the subject of any symbol equation that they write down. Care should also be taken to avoid making any power-of-ten errors.
- (ii) In many cases the arrows drawn on the diagram were poorly labelled or not labelled at all. Weaker candidates tended to draw electric field lines instead of an arrow to represent the direction of the electric force. A small number of candidates drew the weight arrow horizontally, perhaps because they are used to doing questions where the parallel plates are horizontal instead of vertical.
- (iii) Many of the weakest candidates did not attempt a solution to this part of the question. Candidates were usually more successful at determining the magnitude of the resultant force than at determining the direction of the force.
- (c) Only a small proportion of the candidates sketched the correct graph. Many drew an incorrect downward sloping straight line instead of the required curved line.

Question 6

- (a) The majority of candidates knew that an electric current is a flow of charge carriers.
- (b)(i) This question caused little difficulty for stronger candidates. Others tended to make unsuccessful attempts to work backwards from the equation given in (b)(ii).
- (ii) This part of the question worked well at differentiating the candidates. Stronger candidates were able to show a clear and methodical derivation of the correct equation. Candidates of more average ability usually gained partial credit, whereas the weaker candidates often made no attempt at an answer.
- (c)(i) Many candidates realised how to solve this part of the question, but made simple mistakes in their algebraic manipulation. A common mistake was to calculate an answer that was the inverse of the correct ratio.

- (ii) 1. Many candidates were able to recall the relevant symbol equation. Most found it difficult to manipulate the equation to calculate the correct final answer.
2. A correct power formula was usually stated, but many candidates confused the resistance per unit length of the damaged part of the wire with its full resistance.
- (iii) It was generally understood that a reduction in the diameter of the wire causes an increase in its resistance. This increases the power dissipated. Some candidates inappropriately referred to the effect of a change in current, even though the question states that the current remains constant.

Question 7

- (a) It is important that candidates know how to spell the names of all the different particles mentioned in the syllabus so that they can write them unambiguously. Although most candidates knew that positrons are leptons, there were a significant number who stated that they are hadrons.
- (b) Some candidates wisely wrote down the nucleon number and the proton number on each term of the equation to help them determine the answer. Many others were not able to apply the conservation of nucleon number and proton number. A significant minority of candidates confused the number of neutrons with the number of nucleons.
- (c) The majority of answers were correct. Some candidates did not convert the units of kinetic energy from MeV to J. This resulted in the calculated speed of the nucleus being much larger than the speed of light. Such an unrealistic value of speed should have prompted the candidates to quickly re-check their calculation.
- (d) Only a small number of candidates realised that the energy imbalance is due to the emission of a neutrino which carries away some of the energy released by the decay process. There were many vague answers, such as 'energy is lost as heat' or 'mass is converted to energy'.

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Paper 9702/23 AS Level Structured Questions
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Key messages

- Candidates should give clear calculations to numerical questions. The first step should be to state any appropriate symbol equation. It is important that the subject of the equation is clearly shown. The substitution of the data should be presented and then the final answer can be calculated. Candidates who methodically present their calculations in this way are often able to gain partial credit even when an error is made midway through their working.
- Definitions should be recalled 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. 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 check whether their numerical answers have a sensible order of magnitude. If the answer has an unrealistic value, they should quickly review their working to see if a simple error, such as a power-of-ten error, has been made.

General comments

In calculation questions, successful candidates generally tended to write down the formula before substituting and then completing the evaluation. The evaluation of calculations that involved direct substitution of given values into a standard formula was generally well presented and completed accurately. This was particularly noticeable in **Questions 5 and 6**.

In some cases, candidates appeared to give the answer to a question that they thought had been asked rather than the actual question that had been asked. Answers were reproduced that had been learnt rather than which were relevant to the question. This was noticeable in **Questions 2(c)(i), 4(a) and 7(b)**. In some cases a standard answer was given rather than applying their knowledge of physics to the particular situation in the question. This was noticeable in **1(b)(ii), 2(b)(ii), 2(c)(ii), 4(c)(ii) and 7(a)**.

Comments on specific questions

Question 1

- (a) (i) The majority of candidates gave a correct definition. The most common error was to define power as the rate of change of work done.
- (ii) The majority of candidates correctly substituted the base units of all the quantities into a correct equation for power.
- (b) (i) The majority of answers gave the correct base units for area and for thermodynamic temperature. A small minority used °C or s instead of K for the units of thermodynamic temperature. Some candidates correctly put K^4 in the initial expression, but then neglected to give this as K^{-4} in the final expression. Others simply had K in the final expression rather than K^{-4} .

- (ii) The correct curve was given by a minority of candidates. There was little evidence of any working from the given equation such as $P \propto (T^2)^2$. Showing this working may have helped candidates to sketch the curve. Many candidates seemed to have taken a guess as there were many incorrect straight lines from the origin or curves with decreasing gradient.

Question 2

- (a) The majority of candidates gave the initial formulae for pressure and density correctly, but a minority then had difficulty deriving the final expression by combining the two. Some candidates attempted to use an approach using units, which was not appropriate in this case.
- (b)(i) 1. There were many incorrect forces given as the answer including air resistance, contact force, normal reaction force, pressure and gravity. Some candidates repeated the same force and gave drag and friction, weight and gravitational force, or upthrust and buoyancy. Many candidates did not seem familiar with upthrust/buoyancy and referred to 'supporting force' instead.
2. The candidates who correctly identified the three forces usually completed the word equation successfully. A significant number of candidates did not follow the instructions in the question and used symbols rather than words. Some gave an inappropriate equation such as $\text{force} = \text{mass} \times \text{acceleration}$.
- (ii) The majority of the candidates stated that the gravitational potential energy would decrease, but only a small minority related this to the decrease in height of the sphere. The majority simply said that the gravitational potential energy decreases as the sphere falls, which is paraphrasing the question rather than providing an explanation. One of the key points in the stem of the question is that the sphere falls with constant velocity, but many candidates thought that the gravitational potential energy was converted to kinetic energy of the sphere. The conversion of the gravitational potential energy to thermal energy was rarely stated.
- (c)(i) The majority of the candidates found it difficult to interpret the graph. Many candidates gave the pressure at the boundary of the two liquids or the pressure at the base of the container rather than the pressure at the surface of liquid M. A significant number gave a value that they appeared to have recalled from a problem done in the past rather than interpreting the information from the graph. A number of candidates omitted the power of ten from their answer.
- (ii) The majority of the candidates used the expression $p = \rho gh$ but many used data from a single point from the graph which is not appropriate in this situation. Stronger candidates gave correct answers based on Δp and Δh for liquid M.

Question 3

- (a) The majority of candidates showed some appreciation of the principle of conservation of momentum. Some candidates did not include 'total' or 'sum of' when referring to the momentum of bodies. A few candidates wrote that total momentum is 'conserved', but this was repeating information in the stem of the question. A correct statement requires an explanation of what conservation means in this context.
- (b)(i) The stronger candidates gave a full solution in terms of the components of momentum as asked for in the question. A small minority used cosine components rather than sine components. A significant number attempted the calculation using only the components of velocity rather than the components of momentum. This method is not valid and does not follow the instructions in the question.
- (ii) There were some similar errors to those seen in (b)(i), such as missing the mass in the momentum components or the use of the wrong trigonometric function. Many more candidates were able to write at least one correct component of momentum here than in (b)(i).
- (iii) A significant number of candidates wrote their numerical answers without labelling their values as initial or final kinetic energy. Most were awarded credit for the initial kinetic energy. Common errors were using only the horizontal components of velocity to calculate the final kinetic energy or forgetting to include both balls in the calculation of the final kinetic energy.

Question 4

- (a) Many candidates reproduced definitions of longitudinal waves that referred to 'parallel to the wave velocity' or 'parallel to the direction of wave travel'. These were not in the context of the question which specified 'by reference to the direction of propagation of energy...'. Some candidates used vague phrases such as 'the wave oscillates' instead of 'particles oscillate' and could not be given credit.
- (b) The majority of candidates made a good attempt and many achieved full credit. There was a minority of candidates who misread the time period of 2.5 cm from the graph of the c.r.o. screen as 2.4 cm or 2.6 cm, or misread it more comprehensively as 5.0 cm. Some misread the scale of five 2 mm squares to 1 cm. A small minority tried to use $v = f\lambda$ without success.
- (c) (i) Candidates found this question difficult. Stating $I = A^2$ or $I = 1/r^2$ led to incorrect analysis even though reaching the numerically correct answer. Some candidates incorrectly made both constants of proportionality equal to 1 then wrote $A = 1/r$. The key to the analysis was to realise that $I \propto A^2$ and therefore that $A_Y/A_X = r_X/r_Y$.

There were many candidates who incorrectly left in a squared term which gave ratios of 16 or 256. A few candidates were unable to rearrange the equations and so ended up with $A_Y/A_X = r_Y/r_X$. Some who arrived at an equation involving division of fractions ($1/30 / 1/120$) were sometimes unable to complete the final calculation correctly and gave an answer of 0.25 instead of 4.0. Another error by a significant number of candidates was to make distance OX equal to 30 m and distance OY equal to 120 m.

- (ii) 1. The majority of the candidates correctly started with $v = f\lambda$. A large number of candidates then used an incorrect value of frequency (800 Hz being the most common). Those who used the correct value were often not awarded full credit because they gave the answer to three significant figures, rather than the two stipulated in the question. A small number of candidates equated the speed of sound to $3.0 \times 10^8 \text{ m s}^{-1}$.
2. Candidates found it difficult to calculate a correct value for the speed of the car. The appropriate formula is given on the formulae page of the question paper and candidates then had to decide which values of v and f to substitute. The most common error was to subtract 16 from 800 giving an observed frequency of 784 Hz. Another common error was to confuse the observed frequency with the source frequency. A significant number of candidates also confused the velocity of the source with the speed of the sound. A number of candidates did not use the formula at all but simply tried to use a version of $v = f\lambda$ without success.

Question 5

- (a) This question was well answered. A common error was to omit the word 'positive' when referring to the charge.
- (b) (i) The majority of candidates stated the appropriate formula and substituted the correct values. Some attempted to use speed = distance/time to arrive at a value of $3 \times 10^5 \text{ m s}^{-1}$ for the final velocity, and then by manipulation of various numbers appeared to arrive at the given value for the acceleration. This approach is not given credit as the initial expression is incorrect for an object that is accelerating.
- (ii) This question was well answered by the majority of candidates. A small number of candidates used the atomic mass unit rather than the mass of a proton.
- (iii) Both parts were well answered.
- (c) Most candidates assumed that the force acting on the α -particle would be the same as that on the proton, not realising that the charge on the α -particle is twice the charge on the proton and that this would double the force. A significant number of candidates appeared used a mass of an α -particle that was only double that of a proton. Many focused on either the ratio of the masses or the charges, but not both. A significant number left this part blank.

Question 6

- (a) (i) In general, this question was well answered with the formula clearly stated and then the values correctly substituted and evaluated.
- (ii) The majority of candidates could calculate the charge correctly, but sometimes the number of electrons was incorrect. There were a small number of errors which included using $Q = I/t$ rather than $Q = It$ and incorrect calculations of time in seconds. A significant number incorrectly gave the charge as the final answer.
- (b) This question was generally well answered.
- (c) This was also well answered with the formula stated and then the values correctly substituted and evaluated. A common error was to calculate the radius of the wire correctly, but then forget to convert it to diameter. A small number of candidates could not recall the correct equation for resistivity ($R = \rho A/l$ was used by a number of candidates).
- (d) Many candidates gave incorrect answers. There were many incorrect explanations such as 'resistance is proportional to potential difference'. Other misconceptions included the current remaining constant, the current increasing or the power being constant. Some candidates correctly stated that the current decreases but rarely mentioned that this would cause the temperature of the filament wire to decrease. A significant number of candidates stated how the resistance would change but did not give an explanation.

Question 7

- (a) The majority of candidates correctly stated that there are 23 nucleons, but many then went on to state incorrectly that there are 12 neutrons. This may be due to misreading the question and automatically writing down the number of protons instead of the number of neutrons.
- (b) A significant number of answers related to beta decay rather than the properties of the beta particles as asked for in the question. For example, statements such as 'the nucleon number does not change', 'both release energy', 'the nucleus becomes more stable' could not be given credit. A common answer for a difference was that they have a different charge. This was not sufficient as it did not make it clear that they have opposite charges. The answer 'one is an electron and the other is a positron' is almost the same as stating that one is β^- and the other is β^+ , which is merely repeating the question.

PHYSICS

Paper 9702/31 Advanced Practical Skills 1
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Key messages

- 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.
- Candidates are encouraged to record all their raw data (in the table and elsewhere) and show this clearly and not just state the final mean value.
- 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.
- To score highly on **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. General points such as 'avoid parallax error' or 'use more precise measuring instruments' will not usually gain credit without further detail. 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. 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

- (b) Most candidates were able to measure and record the angle θ to be in range and stated the correct unit. Some candidates omitted a unit.
- (c) Many candidates measured and recorded a value of the time T in range and with a unit. Some candidates measured half an oscillation so that their stated time was too small or misread the time to give too high or too low a reading.

- (d) Most candidates were able to collect six sets of values of different θ and T without any assistance from the Supervisor. Some candidates stated T to too few significant figures so that two values came out the same, or made errors in timing that upset the trend.

Many candidates chose a range which was too small so it did not include $\theta \geq 120^\circ$ and $\theta \leq 60^\circ$. Candidates should be encouraged to choose values to make maximum use of the apparatus available.

Some candidates were awarded credit for using the correct column headings in their tables, giving both the quantity recorded and suitable units for T and θ with a separating solidus or brackets around the units. Some candidates stated a correct unit for the T^2/s^2 column heading. Many candidates either omitted the unit or separating mark for this column, or forgot to square the seconds.

Many candidates recorded their raw values for the time to the nearest 0.1 s or 0.01 s, gaining credit. Some candidates did not state the raw values of time and stated only the calculated T to the nearest 0.001 s, so could not be given credit for the consistency of the raw readings. Candidates are encouraged to record all their raw data and marks are awarded for this. Some candidates could not be awarded credit because they rounded their raw values to the nearest second or added a trailing zero to all of their values.

Some candidates recorded their calculated values for T^2 to the number of significant figures in the raw values of the time. Many candidates either stated too many significant figures without relating to their raw readings, or gave the calculated value to too few significant figures.

Most candidates calculated values for $\cos(\theta/2)$ correctly. A few candidates incorrectly calculated $(\cos\theta)/2$. Some candidates made rounding errors in their calculated value whilst others stated $\theta/2$ or did not calculate any value.

- (e) (i) The size and scale of the graph axes were appropriately chosen by some candidates and shown with correct labelling, but many candidates would benefit from taking care over the choice of scale. The scale should be chosen so that the points occupy more than half of the graph grid and it should be easy to read (not based on multiples of 3, etc.). Candidates should be encouraged not to compress the scale to include the origin. They should ensure that the axes are chosen so that all of the points fit on the grid.

There were many incidences of candidates using incorrect numerical scales, often with a missing number or a change in power of ten. Some candidates set the axes with a minimum and maximum based on the minimum and maximum values in the table. This should be discouraged as it gives a scale that is very awkward to use.

Some candidates plotted the wrong graph (e.g. T versus $\theta/2$) or omitted axis labels.

Candidates could improve their graphs by plotting fine crosses (so that the width and height of the 'crossing' are less than half a small square) and plotting the points more accurately with a sharp pencil. If a point seems anomalous, candidates should be encouraged to repeat the measurement to check whether an error in the recording has been made. 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).

- (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, e.g. 14 read off as 10.4.

Some candidates were able to correctly read off the y -intercept at $x = 0$ directly from the graph. Many 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.

- (f) Many candidates recognised that P was equal to the gradient and Q was equal to the intercept. Many candidates recorded a value with consistent units for P and Q (both s^2). Some candidates stated incorrect units while other candidates omitted units.

Question 2

- (a) Many candidates measured values of t in range and to the nearest mm. Some candidates misread the ruler and stated a unit of mm when their value should actually have been in cm.
- (b)(i) Most candidates measured a value of raw d to the nearest mm.
- (c)(ii) The majority of candidates correctly stated h with a unit.
- (iii) The majority of candidates calculated V with a consistent unit, using the same units for D and h .
- (iv) Many candidates were able to relate the number of significant figures to those used in D and h . Some candidates related the number of significant figures to the 'raw data' without detailing the nature of the raw data.
- (e)(v) This measurement was uncertain and needed to be repeated. Some candidates stated a value for y and showed evidence of repeated readings. Many candidates did not give any indication that they had repeated the readings.
- (f) Some candidates were familiar with the equation for calculating percentage uncertainty, although often they made too small an estimate of the absolute uncertainty in the value of y , typically 1 mm. It was awkward to position the nails in the right position and hold the ruler steady, so the uncertainty would be greater than 1 mm. Some candidates repeated their readings and correctly gave the uncertainty in y as half the range, though other candidates did not halve the range. Some candidates stated the uncertainty to be too large (e.g. 1 cm).
- (g) Most candidates recorded a second value of h and y and recorded a value for y which was less than their first value of y .
- (h)(i) Many candidates were able to calculate k for the two sets of data, showing their working clearly. A common error was to rearrange the equation incorrectly to calculate k (using yV instead of y/V).
- (ii) Some candidates calculated the percentage difference between their two values of k , and then tested it against a specified numerical percentage uncertainty. This was accepted when the value was a reasonable reflection of the percentage uncertainty of this experiment. Any criterion provided above 20% needed to be fully justified. Many candidates omitted any criterion. Some candidates referred back to the percentage uncertainty calculated for y and this was given credit. Some candidates gave general statements such as 'this is valid because the values are close to each other' and these were not credited.
- (i) Many candidates recognised that two sets of data were insufficient to draw a valid conclusion. Other commonly stated problems included 'difficult to measure t ' and then citing a valid reason, 'difficult to locate the exact point of the nails' and 'difficult to measure y ' stating a valid reason. Commonly credited solutions were 'take more readings and plot a graph', 'clamp ruler', 'use thinner nails' and 'use marker pens instead of nails'.

Credit is not given for suggestions that could be carried out in the original experiment, such as 'repeat measurements', 'take reading perpendicular to nail'. Vague or generic answers such as 'difficult to measure length' (without stating which length and an associated reason), 'difficult to measure y ' (without stating a reason), 'too few readings' (without stating a consequence), 'faulty apparatus', 'parallax error' 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 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.
- Candidates are encouraged to record all their raw data (in the table and elsewhere) and show this clearly and not just state the final mean value.
- 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.
- To score highly on **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. General points such as 'avoid parallax error' or 'use more precise measuring instruments' will not usually gain credit without further detail. 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

- (b)(ii) Many candidates correctly stated their answer in range and with a unit. Some candidates measured the total time and then mistakenly divided by 10 so that the time stated was too small, misread the stopwatch or measured the time until the mass completely came to rest (e.g. 264 s) rather than ignoring the swinging at the end.
- (iv) Some candidates repeated the time b and wrote their evidence of repeated readings clearly. Many candidates did not repeat the measurement. Some candidates again mistakenly divided their answer by 10.

- (c) Most candidates were able to collect six sets of values of different m , a and b without any assistance from the Supervisor and, in many cases, showing a correct trend. Some candidates stated a or b to too few significant figures so that two values came out the same, or made errors in the timing that upset the trend.

Many candidates did not extend their range of m values to include $m = 10$ g and 70 g. Candidates often increased their values from $m = 10$ g to $m = 60$ g or decreased from 70 g without extending below $m = 20$ g.

Some candidates were awarded credit for using the correct column headings in their tables, giving both the quantity recorded and suitable units for m , raw a and b with a separating solidus or brackets around the units. Some candidates stated a correct unit for the a^2/b column heading. Many candidates either omitted the unit or separating mark for this column.

Many candidates recorded their raw values for a and b to the nearest 0.1 s or 0.01 s, gaining credit. Some candidates did not state the raw values of time and stated only the calculated T to the nearest 0.001 s, so could not be given credit for the consistency of the raw readings. Candidates are encouraged to record all their raw data. Some candidates could not be awarded credit because they rounded their raw values to the nearest second or added a trailing zero to all of their values.

Some candidates recorded their calculated values for a^2/b to the number of significant figures recorded in the raw values of a and b . Many candidates either stated too many significant figures without relating to their raw readings, or gave the calculated value to too few significant figures.

Some candidates calculated values for a^2/b correctly. Other candidates incorrectly calculated a/b , b^2/a or a/b^2 . Some candidates made rounding errors in their calculated value.

- (d)(i) The size and scale of the graph axes were appropriately chosen by some candidates and shown with correct labelling, but many candidates would benefit from taking care over the choice of scale. The scale should be chosen so that the points occupy more than half of the graph grid and it should be easy to read (not based on multiples of 3, etc.). Candidates should be encouraged not to compress the scale to include the origin. They should ensure that the axes are chosen so that all of the points fit on the grid.

There were many incidences of candidates using incorrect numerical scales, often with a missing number or a change in power of ten. Some candidates set the axes with a minimum and maximum based on the minimum and maximum values in the table. This should be discouraged as it gives a scale that is very awkward to use.

A few candidates plotted the wrong graph (a/b versus m) or omitted axis labels.

Candidates could improve their graphs by plotting fine crosses (so that the width and height of the 'crossing' are less than half a small square) and plotting the points more accurately with a sharp pencil. If a point seems anomalous, candidates should be encouraged to repeat the measurement to check whether an error in the recording has been made. 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).

- (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, e.g. 38 read off as 30.8.

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

- (e) Many candidates recognised that P was equal to the gradient and Q was equal to the intercept. Many candidates recorded a value with consistent units for P (s g^{-1}) and Q (s). Some candidates stated incorrect units or omitted units. A few candidates identified m in the equation as the gradient and not the mass.

Question 2

- (a) (ii) Many candidates measured values of c in range. Some candidates stated c as being less than 95 cm when the question asks that the loops are as close to the ends of the rule as possible.
- (c) (ii) Most candidates measured a value of x in the appropriate range.
- (iv) The majority of candidates correctly stated raw values of z to the nearest mm. A few candidates who routinely used 3 significant figures were not awarded credit because they added an extra zero, e.g. 6.50 cm.
- (d) Some candidates made too small an estimate of the absolute uncertainty in the value of z , typically 1 mm. It was awkward to judge the ends of the spring and hold the ruler steady close to the coil without disturbing the spring, so a better estimate of the uncertainty would be larger than 1 mm. Some candidates repeated their readings and correctly gave the uncertainty in z as half the range, although other candidates using this method did not halve the range. Some candidates stated the uncertainty to be too large (e.g. 1 cm).
- (e) (i) Many candidates calculated $(x - c/2)$ correctly using the same units for x and c .
- (ii) Many candidates correctly calculated $(z - y)/m$ stating an appropriate unit consistent with their values used. Some candidates omitted units.
- (f) Candidates found it difficult to justify the number of significant figures they had given for the value of $(z - y)/m$ and give reference to the number of significant figures used in z , y and m or m and $(z - y)$. Many candidates gave reference to just 'raw readings' without stating what the raw readings were, or related their significant figures used to just one or two of the individual quantities, often omitting m . A few candidates incorrectly referred to the number of decimal places in z , y or m instead.
- (g) (ii) Most candidates recorded a second value of x and z , and recorded a value for z which was greater than their first value of z with the smaller mass.
- (h) (i) Many candidates were able to calculate k for the two sets of data, showing their working clearly. A common error was incorrectly rearranging the equation to calculate k or using m twice in the calculation.
- (ii) Some candidates calculated the percentage difference between their two values of k , and then tested it against a specified numerical percentage uncertainty. This was accepted when the value was a reasonable reflection of the percentage uncertainty of this experiment. Any criterion provided above 20% needed to be fully justified. Many candidates omitted any criterion. Some candidates referred back to the percentage uncertainty calculated for z and this was given credit. Some candidates gave general statements such as 'this is valid because the values are close to each other' and these were not credited.
- (i) Many candidates recognised that two sets of data were insufficient to draw a valid conclusion. Other commonly stated problems included 'difficult to make the rule horizontal to the bench', 'difficult to measure x (or c) because the markings were obscured by the thickness of the string' and 'difficult to measure y or z because of parallax error'. A less frequent source of uncertainty

was 'large uncertainty in $(z - y)$ '. Common valid solutions were 'take more readings and plot a graph', 'use a spirit level', 'use thinner string' and 'use a larger range of masses'.

Credit is not given for suggestions that could be carried out in the original experiment, such as 'repeat measurements', 'take reading perpendicular to spring', 'wait for the system to stop oscillating to take readings', 'measure height at both ends of the rule' or 'add weights carefully to prevent the rule oscillating'. Vague or generic answers such as 'difficult to measure lengths' (without stating which length and an associated reason), 'difficult to measure x or y ' (without stating a reason), 'too few readings' (without stating a consequence), 'ruler sliding out of string loops' (without stating which measurement is affected), 'parallax error' etc. were also not given credit, and similarly for unrealistic solutions e.g. 'remove air from the room'.

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 9702/34 Advanced Practical Skills 2
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Key messages

- 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.
- Candidates are encouraged to record all their raw data (in the table and elsewhere) and show this clearly and not just state the final mean value.
- 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.
- To score highly on **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. General points such as 'avoid parallax error' or 'use more precise measuring instruments' will not usually gain credit without further detail. 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

Experiments are designed with the view that only the equipment specified in the Confidential Instructions is provided to candidates. Additional equipment such as vernier calipers or micrometers, for example, should not be provided unless explicitly included in the list of apparatus in the Confidential Instructions. It may disadvantage candidates if they are provided with additional equipment.

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.

Graph scales should be chosen so that the plotted points occupy a good proportion of the graph grid (at least half), avoiding 'compressed' scales. Increasing numbers of candidates are taking this to extremes by using the smallest and largest values of a quantity to be plotted as the beginning and end of the scale markings on the graph grid, and then calculating intermediate values. These scales are difficult to use and are not awarded credit. Moreover, candidates using such scales often make plotting errors and read-off errors when calculating a gradient or y-intercept value. Scale markings should be simple (ideally integer) values.

The general standard of the work done by the candidates was good. 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

- (b)(ii) Most candidates recorded a value for T that was in the range 1.00–2.00 s. A few candidates either misread the stopwatch, recording values of T such as 0.001 s, or recorded the value for, e.g., five oscillations but forgot to divide their answer by five.

Fewer candidates repeated their measurement of the time for multiple oscillations. Measuring the time for one oscillation, several times, is not sufficient. As a general rule, the time for at least five complete oscillations should be repeated two or three times, and a mean value calculated (not forgetting to divide the mean value by the number of oscillations to find T). All working should be shown, including the value of n , where n is the number of oscillations.

- (c) Almost all candidates recorded six values of m , T and T^2 correctly, showing the correct trend.

Some candidates chose values of m to give the widest possible range of values. Others needed to use a wider range of values. In any experiment, it is good practice to try to include both the smallest and largest values possible, and then select approximately equally-spaced intermediate values.

Most candidates were awarded credit for using the correct column headings in their tables, giving both the quantity recorded and suitable units for each quantity, with the two separated by a solidus, or with the units in brackets. A few candidates recorded the units for T^2 as s rather than s^2 or used 'gm' rather than g as the symbol for grams.

Most candidates recorded all their raw values of time to the nearest 0.1 s or all to the nearest 0.01 s. Some candidates were not awarded credit because they recorded only mean values of T to 0.001 s. Raw readings of a quantity should always be recorded, and to the same precision (in this case that of the stopwatch), and not necessarily to the same number of significant figures.

Most candidates calculated their values for T^2 correctly; each calculated value should be recorded to the same number of significant figures as (or one more than) the number of significant figures of the value of raw time.

- (d)(i) Candidates were required to plot a graph of T^2 on the y-axis against m on the x-axis. Most gained credit for drawing appropriate axes, with labels and sensible scales. Some others chose extremely awkward scales, which are not awarded credit and make the correct plotting of points and subsequent graphical work much more difficult. 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).

The majority of candidates were awarded credit for the quality of their data.

- (ii) Some 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 (to within half a small square in both directions).

- (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 (e.g. $\text{s}^2 \text{g}^{-1}$) and b (s^2). Others omitted the units for a and b . The units for a and b can be derived directly from the quantities plotted on the graph and confirmed by the equation given in (e).

Question 2

Candidates were asked to investigate an optical system consisting of a convex lens, a torch and a screen. Some Centres were unable to provide the lens specified in the Confidential Instructions, so notified Cambridge and substituted a different lens (usually with a longer focal length than that specified). Examiners were able to adjust the mark scheme as appropriate, provided details of the changed apparatus were given in the Supervisor's Report.

- (b)(iii) Most candidates recorded a value of u in the appropriate range. A few candidates omitted the unit.
- (v) Most candidates recorded a value successfully, though some were not awarded credit because they did not give their value to the nearest 0.1 cm.
- (c) Candidates were asked to estimate the percentage uncertainty in their value of v . Most were familiar with the equation for calculating percentage uncertainties, but many underestimated the absolute uncertainty in the value of v . The uncertainty is dependent not only on the precision of the metre rule, but also on the possible errors in judging the centre of the lens, for example. A realistic estimate for the absolute uncertainty in v is 2–8 mm.
- (d) Almost all candidates were able to calculate the value of f correctly, using the equation given. A few candidates rounded their answer incorrectly. A value of 4.745, for example, rounds to 4.75 when recorded to 3 significant figures, but 4.7 to 2 significant figures.
- (e)(iii) Almost all candidates achieved credit for recording the new value of the distance v_w between the lens and the image. Credit was awarded for obtaining a value greater than the original value of v , and this was also achieved by most candidates.
- (f) Candidates were asked to justify the number of significant figures given for their calculation of the new effective focal length of the lens, f_w . Some stated correctly that the number of significant figures for f_w is determined by the significant figures of u and v_w (whichever is the smaller); others gave answers which were too vague, referring only to the 'raw data', so were not awarded credit.
- (g)(ii) Almost all candidates were awarded credit for recording a second value for u that was in the range 20.0–24.0 cm, and also recorded a second value for v . Credit was also available for quality, for those candidates who obtained a second value for v_w that was greater than the first value of v_w , as recorded in (e)(iii).
- (h)(i) Most candidates were able to calculate the two values for k correctly. Some calculated $1/k$, or chose the wrong quantities for their calculation.

- (ii) Most candidates calculated the percentage difference between their two values of k , and then tested it against a specified numerical percentage uncertainty, either taken from (c) 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.

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.

- (i) 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 measuring the distances u and v accurately, judging the exact position where a sharp image of the torch LEDs is formed on the screen, and keeping the screen steady. The vertical alignment of torch and lens was also a significant cause of uncertainty in the measurements.

Some candidates simply described measurements that were difficult to make without explaining why they were difficult, e.g. 'it was difficult to measure u ' or 'difficult to measure the distance between the screen and the lens'. A reason for the difficulty is also needed in order to gain credit, e.g. 'it was difficult to measure u accurately because it is hard to judge the centre of the lens/the front of the torch/there is parallax error when judging the centre of the lens'.

Valid improvements included taking more readings for different values of u and then plotting a suitable graph to test the suggested relationship. Some 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.

Some candidates suggested improvements which should have been carried out in the original experiment such as repeating measurements and calculating average values, or limiting parallax errors by reading the ruler 'square on'. No credit is given for these suggestions.

PHYSICS

Paper 9702/35 Advanced Practical Skills 1
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Key messages

- 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.
- Candidates are encouraged to record all their raw data (in the table and elsewhere) and show this clearly and not just state the final mean value.
- 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.
- To score highly on **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. General points such as 'avoid parallax error' or 'use more precise measuring instruments' will not usually gain credit without further detail. 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

Centres generally did not have any difficulties in providing the equipment required for use by the candidates. Any deviation between the requested equipment and that provided to the candidates should be written down in the Supervisor's Report, and this report must be sent with the scripts to Cambridge so that the Examiners can take this into consideration when marking. No 'extra' equipment should be available to the candidates. In some cases this may disadvantage candidates.

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

In **Question 1**, successful candidates connected the circuit correctly, took an accurate set of measurements leading to a graph with the correct trend and completed the analysis correctly. Before candidates begin experimenting, they need to look carefully at the apparatus given. It is a worthwhile use of time to consider the range of readings that can be taken. On this question, successful candidates used the full range of resistors available, using both a $10\ \Omega$ and a $33\ \Omega$ resistor.

In **Question 2**, successful candidates were able to manipulate the pendulum and take time measurements accurately. The most successful candidates repeated and recorded these repeated measurements, made a valid estimate of Δx the absolute uncertainty in x , and stated clear, valid limitations and improvements.

Comments on specific questions

Question 1

- (a) (iii) Successful candidates were able to set up the circuit correctly, placing the voltmeter in parallel with the wire, then read and record a voltmeter reading in the appropriate range and with the required precision, and write down the unit V.
- (b) (iv) With a correctly connected circuit, the value of distance q was greater than distance p and successful candidates gave readings with this pattern including correct units for both p and q e.g. 52.3 cm. Weaker candidates sometimes omitted the unit or used an incorrect unit e.g. 52.3 or 52.3 m.
- (c) Successful candidates included six sets of values of p , q and R in neatly presented tables, and their values had the correct trend.

Before taking readings, the strongest candidates benefited from looking carefully at the resistor values available. To make full use of the apparatus, they needed to use the smallest ($10\ \Omega$) and the largest ($33\ \Omega$) resistors.

Many candidates drew neat, well-constructed tables, and included a correct quantity and unit in every column heading. These candidates remembered to include a separating mark, such as a solidus, between the quantity and unit e.g. p/cm , q/cm , $q/R\ (\text{cm}/\Omega)$ and gave q/p on its own without a unit. Weaker candidates sometimes used a comma as the separator or gave a unit for q/p .

The metre rule provided had millimetre markings and stronger candidates used mm when recording their values of p and q . Some candidates did not give values to the nearest mm e.g. 25 or 53.50.

Each value of resistance was given to 2 significant figures, and so candidates needed to give their values of q/R to 2 or 3 significant figures.

Candidates were asked to calculate q/p , and stronger candidates were able to do this and round their answers correctly.

- (d) (i) Candidates should take care to use axes that are labelled with the appropriate quantities i.e. q/p or q/R , and they should not use a unit alone to identify the axis. Successful candidates used scales that were easy to interpret, e.g. a value of 1 was equivalent to 10 small squares. Some candidates used scales that were not easy to use, such as 1 equivalent to 15 small squares. In this example 1 small square corresponds to 0.067 and it is almost impossible to use this scale accurately.

Candidates should be encouraged to choose a scale that spreads the points over more than half the grid. Before candidates plot their points, they need to consider how much of the grid the points will occupy. This can be done by looking at the maximum and minimum values in the table.

Some graphs could be improved by plotting fine crosses (so that the width and height of the 'crossing' are less than half a small square) and plotting the points more accurately with a sharp pencil.

- (ii) A single line was drawn on the grid by successful candidates, with a good balance of points about the line. Others correctly drew a line using five trend points but identified one anomalous point. When a point is identified as anomalous for the purposes of drawing the line of best fit, this point should be clearly indicated on the graph by adding a label or by drawing a small circle around the point. If a point seems anomalous, candidates should be encouraged to repeat the measurement to check whether an error in the recording has been made.

Some candidates joined the first and last points on the graph regardless of the distribution of the other points. There should always be a balanced distribution of points either side of the line along the entire length. Many lines needed rotation to get a better fit. 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).

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

- (e) Many candidates identified that a was equal to the value of (and with the same sign as) the gradient and b was equal to the value of the intercept. Consequently, they made a direct transfer of the values in (d)(iii) to (e). This recognition meant that no calculation was done (or needed) to find a and b . Some weaker candidates recorded fractions for a and b . Some candidates stated incorrect units or did not include units.

Question 2

- (a) Successful candidates measured the correct quantity L of the string loop, stating the length with its unit. They realised that holding the ends of the loop and measuring L at the same time was difficult and used this as a valid limitation in (f).
- (b)(ii) Because the loop was suspended, candidates had to pull down on the loop and identify the end points, so the distance x was difficult to measure. Successful candidates recorded the value of x to the nearest mm and gave the unit as cm or m. Realising the difficulty in the measurement, stronger candidates repeated the reading and noted down the repeats. They also used this as a limitation in (f).
- (iii) Stronger candidates had considered the difficulties involved in measuring x . When deciding on the absolute uncertainty for x , they gave a value between 2 mm and 8 mm. The smallest division on the rule (1 mm) was an unreasonably small estimate of the uncertainty.

When readings were repeated, some candidates found the absolute uncertainty by calculating half the range of the repeated values. These candidates realised that the half-range calculation needed to be shown so that it was clear how the estimate of absolute uncertainty had been produced.

- (iv) Many candidates correctly calculated a value for G , ensuring that the units of the quantities L and x used were the same (i.e. either both cm or both m).
- (v) Successful candidates clearly related the number of significant figures in their values of x and L to the number of significant figures in their value of G . A successful statement could be 'the value of G was given to the same number of significant figures as (or one more than) the number of significant figures in x and L dependent on the quantity with the smallest number of significant figures'. Successful candidates explicitly stated x and L (i.e. the quantities relevant to this question). Candidates should be encouraged not to simply state 'raw data' or use the vague phrase 'values in the calculation'. Some candidates referred to decimal places and some gave a bald statement such as '3 significant figures', neither of which could be awarded credit.
- (c)(ii) Most candidates were able to tie the string to make a pendulum and recorded the times for repeated oscillations, calculating a period in the correct range and stating the unit of s. Some candidates incorrectly calculated n /time rather than time/ n .
- (d) Most candidates were able to set up the second pendulum and record second values of L , x and T . Most candidates correctly found that a smaller value of x produced a shorter period.
- (e)(i) Many candidates successfully rearranged the equation and calculated k correctly to at least 2 significant figures for both experiments. Some candidates found it difficult to rearrange the equation and used $k = (G + x) / T^2$, or did not remember to square T .

- (ii) Some candidates calculated the percentage difference between their two values of k , and then tested it against a specified numerical percentage uncertainty. This was accepted when the value was a reasonable reflection of the percentage uncertainty of this experiment. Any criterion provided above 20% needed to be fully justified. Some candidates referred back to the percentage uncertainty calculated in (b)(iii) and this was given credit. Some candidates gave general statements such as 'this is valid because the values are close to each other' and these were not credited.

- (f) **Question 2** is designed to have challenges when taking measurements. The most successful candidates generally think about limitations while doing the experiment and then make valid suggestions here. Many candidates approached this question well.

A large number of candidates realised that only two pendulums were used to test the relationship, and they stated that 'two readings were not enough to draw a conclusion'. Some weaker candidates simply stated 'two readings are not enough' or 'two sets of readings are not enough to take accurate readings'.

The measurement of x was difficult. Rather than stating 'it was difficult to measure x ', stronger candidates included a reason to explain why it was difficult to measure x such as 'it was difficult to measure x as the stands tilted towards each other when the loop was pulled'. With L , rather than stating 'it was difficult to measure L ' the stronger candidates would write 'when measuring L the reading is not accurate because my fingers cover the ends of the loops.' When identifying solutions, these candidates detail how to improve the measurement. Rather than stating 'improve the measurement of L ' or 'use better apparatus to measure L ', they would state, for example, 'use pins to fix the ends of the loop on the metre rule to measure L '.

Successful candidates realised they could use the metre rule to ensure that the rods of the clamps were at equal heights above the bench, so they did not state this as a limitation. They also realised that amplitude or release force are not factors which affect the period of the oscillations of the pendulum.

Some candidates suggested the use of a 'card gate' or the lubrication of rods to reduce friction, neither of which were valid improvements to this experiment. Weaker candidates were often distracted by ideas relating to air movement/air conditioning/air resistance and these also were not significant sources of uncertainty or limitations in the experiment.

Credit is not given for suggestions that could be carried out in the original experiment, such as 'repeat measurements', 'take reading perpendicular to ruler' etc. 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 9702/36 Advanced Practical Skills 2
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Key messages

- 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.
- Candidates are encouraged to record all their raw data (in the table and elsewhere) and show this clearly and not just state the final mean value.
- 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.
- To score highly on **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. General points such as 'avoid parallax error' or 'use more precise measuring instruments' will not usually gain credit without further detail. 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. Help from Supervisors was rarely necessary and, where it was given, Centres gave clear details of the assistance.

The general standard of the candidates' work was good. Some candidates could improve their presentation by writing numerical data and descriptive answers more clearly. Most calculations were carried out accurately, nearly always including correct rounding of the final values.

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

Comments on specific questions

Question 1

- (c) (ii) Most candidates recorded a value for T in the expected range, although in a few cases the unit was missing. For values out of range, the candidate had probably measured the time for n oscillations and then forgotten to divide by n .
- Many candidates were awarded credit for recording repeat measurements of nT .
- (e) Most candidates recorded six sets of values of x and T in a tidy table without any assistance from the Supervisor. Some did not record their values of nT (i.e. the actual measurements). In a few cases, full credit could not be given because values of x were not included in the table, or because each increase in x did not produce a decrease in T .

A small number of candidates did not include measurements with a large enough range (i.e. including a value of x close enough to $L/2$).

Most candidates gave correct column headings and units. A few gave the unit for $1/T^2$ as s^2 (rather than s^{-2}), or omitted the unit altogether.

All measurements of x should have been recorded to the nearest mm. The values for x were selected by the candidate, and therefore they could all be in whole cm, but they should still be recorded to the nearest mm (e.g. 18.0 cm or 0.180 m).

The calculated values of $(x - L/2)$ were usually correct.

- (f) (i) Most 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.

Scales were usually simple, so it was easy to avoid mistakes when reading coordinates off the grid. In some cases, the points were drawn using dots that were either too large or so small that they were obscured by the line. It is safer to use small crosses.

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

- (ii) Many candidates drew good lines of best fit, with a balanced distribution of points either side along the entire length. In a small number of cases the line was not straight, and some ignored a stray point but without marking it as anomalous.

- (iii) Most candidates knew how to find the gradient and intercept of their line, carried out the procedure accurately and showed their working clearly. Usually the intercept value had to be calculated rather than reading it directly off the $1/T^2$ axis.

- (g) Most candidates recognised that a was equal to the value of the gradient and b was equal to the intercept (as calculated in (f)(iii)). Some candidates chose to present their final answer to only 1 significant figure, which did not gain credit.

Most candidates included correct units for their values of a and b .

Question 2

- (a) (iv) Nearly all candidates recorded a value for D to the nearest mm and included a correct unit.

- (b) (ii) Most values of h_1 were in the expected range, and very few candidates omitted a unit.

- (c) When measuring h_1 , the metre rule could stand on the bench and so the only uncertainty was the scale reading at the wooden strip, giving an uncertainty in h_1 of 1 mm. Many candidates used an uncertainty of 2 mm or more in their percentage uncertainty calculation, but there was no reason for the uncertainty to be this large, so these estimates were not awarded credit.

- (d) (ii) Candidates generally had no difficulties calculating the deflection d .

- (f) (ii) Most candidates recorded sensible values and units for their measurements of t and w . Some candidates were concerned that the value of t (3 mm) had only one significant figure and so they added a spurious zero (e.g. 0.30 cm). This was not awarded credit because the apparatus available did not justify this precision.

- (iii) This calculation involved careful transfer of values into the expression (a few candidates used d instead of D). In most cases it was carried out well, including sensible rounding and a unit consistent with a Young modulus value.

- (g) The second set of measurements (using eight masses) was recorded by most candidates, and most obtained the expected trend in the deflection d .

- (h) (i) Most candidates calculated k correctly for each of the two sets of measurements, though in a few cases their value was rounded incorrectly.

- (ii) When justifying the number of significant figures given for k , stronger candidates explained the dependence on the significant figures of their d and p values.
- (iii) Many candidates carried out a sensible comparison of their two k values and most were able to make a sensible assessment, based on calculation, of whether the two values were close enough to support the suggestion.
- (i) The strongest candidates identified problems associated with carrying out this particular experiment and in obtaining readings, and gave sufficient detail of both the problem and of a method of overcoming it.

For the measurement of the small distances, particularly t , the percentage uncertainty was very large. Candidates are quite right to be unhappy about using a ruler to measure a small quantity, but they have difficulty describing why the ruler is unsuitable. It is a simple matter to use the ruler to find a value accurate to the nearest mm, so the phrases 'it is hard to measure t with a ruler' or 'it is inaccurate to measure t with a ruler' are not correct. The problem is with the precision of the ruler and the small value of t , since $3 \text{ mm} \pm 1 \text{ mm}$ gives an uncertainty of 33%. Candidates need to say ' t is small so the uncertainty is large when using a ruler' or 'for t the percentage uncertainty is large'. A valid improvement would be to use vernier calipers or, in the case of t , a micrometer.

One of the important differences between a metre rule and a 30 cm ruler is that the ruler has a 'margin' at each end of its scale whereas the scale on a metre rule starts right at the end of the rule. This makes the metre rule much more suitable for measuring a height above a bench since the zero of its scale can rest on the bench.

Some candidates suggested improvements which should have been carried out in the original experiment such as repeating measurements and calculating average values, or limiting parallax errors by reading the ruler 'square on'. No credit can be given for these suggestions.

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 confuse are atom, molecule and nucleus; heat and temperature; 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.
- Candidates are encouraged to consider whether their answers to numerical questions make sense. Identifying that an answer cannot possibly have a particular order of magnitude (such as a speed greater than the speed of light) or be outside a particular range (such as a p.d. in a circuit greater than the supply p.d.) is often a good way of determining that a mistake might have been made.
- 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.

General comments

Some weaker candidates find converting powers of ten and unit conversions troublesome. This year some candidates had problems converting MeV to J, km to m and mass numbers into kg.

The use of singular and plural terms can cause difficulty but can be important. For example, in **Question 9(a)**, candidates need to be clear whether they are referring to a single slice or to multiple slices.

Many candidates are better at calculations than they are at descriptive answers. Practice at questions from past exam papers might help candidates with this, as would paying careful attention to the mark schemes and Principal Examiner Reports for Teachers.

Very few candidates explain any mathematical substitutions they make, and this can make it unclear how the different lines in the candidate's working are related. Sometimes there is a scattering of formulae in the margin of the answer space. It is not possible to award credit for a list of unconnected formulae when a question asks candidates for a derivation. Candidates should be encouraged to state the formulae they use clearly.

Comments on specific questions

Question 1

- (a) (i) The most common misconception was that objects at different temperatures always have different amounts of internal energy.
- (ii) Candidates often did not realise that they needed to refer to thermometric/physical properties of materials.

- (b) A common incorrect suggestion was that the thermometers had different sensitivities. Many candidates wrote about the heat capacity of the thermometers being different and so took different times to show the correct temperature. Very few responses showed that candidates realised that the thermometric properties may not behave linearly.
- (c) (i) The calculation was generally well executed. A significant number of candidates made life difficult by adding and then subtracting 273 from the temperature in their calculations.
- (ii) The line on the graph was frequently correct and the calculation was generally well executed.

Question 2

- (a) Candidates found this question difficult. Most answered with reference to angular velocity and circular motion rather than angular frequency and simple harmonic motion. If a formula is used to define a quantity, then candidates need to define the terms in their formula in order to receive credit.
- (b) (i) Even the more able candidates found it difficult to determine these two displacements. There was a lot of information in the question before the answer lines and successful candidates would have read the information carefully before considering the graph. These questions were asked to help the candidates use the correct displacement in the calculation in (iii).
- (ii) Few candidates mentioned the fact that the equilibrium position was at $a = 0$ and $s = 2.0$ cm. Whilst most candidates knew that the two necessary conditions for simple harmonic motion were proportionality with acceleration and displacement in opposite directions, only the stronger candidates related these conditions to the straight line and its negative gradient.
- (iii) Stronger candidates generally arrived at the correct value. The weaker candidates tended to use coordinates directly from the graph without subtracting 2.0 cm from the value of the displacement, which was needed before using the formula $a = (-)\omega^2 x$. A common mistake was to forget to convert a value in centimetres into metres. A few candidates used the gradient rather than the reciprocal of the gradient.

Question 3

- (a) Most candidates knew this definition, but some mixed it up with gravitational potential and gravitational potential energy. The 'per' is required to explain the division of the force by the mass. Candidates should avoid writing 'per kg' as units should not be used in the definition of a quantity.
- (b) A common mistake amongst weaker candidates was not to compare the very small change in height h with the radius of the Earth. Of the candidates who did make a valid comparison, the strongest correctly stated that either $g = GM/R^2 \approx GM/(R + h)^2$ or stated that, for such comparatively small changes in h , the field lines are almost parallel and the field would effectively be constant.
- (c) Answers to this calculation were good and usually well presented. Candidates have seen this type of question before and they clearly understood what was required. Some candidates did not explain where the centripetal force arises. In addition, there were some mistakes of forgetting to square or cube numbers and forgetting to change into SI units.

Question 4

- (a) Many weaker candidates listed the advantages of the coaxial cable over other types of cable, rather than the function of the copper braid.
- (b) Weaker candidates performed better on this part of the question. The most common correct suggestions involved smaller bandwidth and increased interference. Many candidates referred to the security of the signal, but the context of the question was a television aerial, so this suggestion did not gain credit.

- (c) Most candidates could calculate a value of the attenuation of 2.66 dB and could state that attenuation was given by an expression of the form $-10 \lg (P_2/P_1)$. Weaker candidates tended to arrive at either $P_{\text{OUT}}/P_{\text{IN}} = 1.85$ or $P_{\text{IN}}/P_{\text{OUT}} = 0.54$, because they had used either $10 \lg (P_{\text{OUT}}/P_{\text{IN}})$ or $-10 \lg (P_{\text{IN}}/P_{\text{OUT}})$. The strongest candidates went on to calculate the fractional loss correctly.

Question 5

- (a) (i) Most candidates stated Coulomb's law correctly. Some candidates referred to the product of two masses in the statement of the law. Candidates should be encouraged to re-read their answers in order to avoid mistakes like this.
- (ii) Most candidates could draw a downwards curve on the graph of decreasing gradient. Some candidates did not gain credit because their curves did not start from (R, F_C) or did not pass the relevant points of $(2R, 0.25F_C)$ and $(4R, 0.06F_C)$.
- (b) This question discriminated well. Weaker candidates often copied the original line, or drew a reflection of it. More able candidates were able to use the gradient of the original line to get the line for the induced e.m.f. Only the strongest candidates noted the correct difference in magnitude of the two gradients between t_1 and t_2 , and t_3 and t_4 .

Question 6

- (a) (i) Most candidates knew how to calculate the capacitance of a combination of capacitors, although a common mistake was to use the formulae the wrong way around and end up with $3C/2$ instead of $2C/3$. Some candidates did not realise that the capacitors all had the same value of capacitance, and made life very difficult with a complicated method.
- (ii) Although 6 V was a very common answer, it wasn't always clear that the candidates knew how they had reached their answer and consequently credit could not be awarded for the explanation. The key to the explanation is the fact that the charge is the same on the single capacitor and the parallel combination.
- (b) Some candidates wrote that the two capacitors reached a voltage of 4.5 V. Of those candidates who correctly stated that the voltage across P would fall and that across Q would increase, only a limited number gave any valid explanation along the lines that capacitor P would discharge through the resistor R whilst at the same time capacitor Q would charge. Candidates often did not mention the final voltages of 0 V and 9 V once discharging or charging had occurred.

Question 7

- (a) (i) Candidates' explanations of the circuit's virtual earth were generally good. Most candidates would point out V^+ was connected directly to earth. All but the weakest candidates could explain that the op-amp's infinitely large gain would lead to saturation, although less able candidates tended not to state that, in order to avoid saturation, V^- must be equal or close to V^+ .
- (ii) Nearly all but the very weakest candidates could at least state that $\text{gain} = -R_2/R_1$. The majority of candidates made a reasonable attempt at deriving this expression. Only the more able candidates would preface their derivations by stating that the current in R_1 would equal the current in R_2 because the op-amp's input impedance is infinite.
- (b) This graph again discriminated well between candidates. Most candidates drew an inverted shape correctly and worked out that the gain of 4.5 would lead to a voltage of $4.5 \times 3 \text{ V} = 13.5 \text{ V}$. Many candidates did not take into account the fact that the op-amp had a supply voltage of $\pm 9 \text{ V}$ and so would saturate at 9 V. Of those who limited their output signal graphs to 9 V, about half drew both ends of the horizontal line occurring at correct times.

Question 8

- (a) The majority of candidates could do this correctly, giving four letters for each face (DERQ and CFSP). Some weaker candidates gave only two letters relating to a face and this was insufficient to identify the faces.
- (b)(i) This derivation proved fairly straightforward for most candidates, but some found it difficult to derive $V_H = Bvd$ because they used $F = BIL$, rather than $F = Bqv$.
- (ii) Most candidates, even if they had not derived it in (i), recalled the equation $V_H = Bvd$ as a starting point. The majority could introduce the formula $I = nAqv$ and reached $V_H = BId/nAq$. Weaker candidates tended not to explain why d/A became t in their expression.
- (c) Only the stronger candidates suggested that, as copper is a metal, the charge density n is very large and therefore V_H would be very small and difficult to detect. Most candidates tended to base their responses on the thickness of the slice and did not gain credit.

Question 9

- (a) There were some good responses. Weak responses were quite common, often because candidates confused the concepts of a slice and an image, and would refer to a slice of an image rather than an image of a slice. Also, weaker responses tended to lack a logical order and either go into too much detail (such as including detailed information about voxels) or include irrelevant details such as how X-rays are produced. Some of the best answers were often the briefest.
- (b) Many correct answers were given. A few candidates subtracted the background and then stopped. Candidates doing this might have been thinking logically, realising that the background should not be counted, but did not know how to proceed.

Question 10

- (a) Weaker candidates tended incorrectly to base their answers upon either back e.m.f. or upon eddy currents. Some introduced the idea that the root-mean-square current would be non-zero but then did not build on this concept to explain why the power dissipated would be non-zero.
- (b)(i) Most candidates realised that a high voltage meant a low current and that this meant less power loss, but they did not always say that the power remained constant.
- (ii) Most candidates realised that alternating voltages could be easily transformed, but not that transformers only worked with alternating current.

Question 11

- (a) Most candidates were able to state what is meant by a photon. A minority did not refer to energy.
- (b) These calculations were straightforward for those candidates who knew the formulae. There were some power of ten errors and some forgot to convert from eV into J.
- (c) This question was well answered. A fairly common power-of-ten mistake was to calculate the mass of the indium-123 nucleus in gram using $\text{mass} = 123/N_A$ and then forget to convert this into kilogram.

Question 12

- (a) Some candidates overlooked the statement that radiation is emitted in all directions and that the detector does not surround the source, and gave this as one of their reasons. Some weak responses were too vague to gain credit, such as 'the radiation does not reach the detector'.
- (b)(i) This was well answered by candidates. Some candidates explained that the curve showed exponential decay, which is a characteristic of radioactive decay but not of the randomness of radioactive decay.

- (ii) Most answers were mathematical rather than graphical. In answering this type of question, candidates should be encouraged to take more than one half-life and average. The fact that there was a background count or systematic error, which is clear when considering the count rate at later times, was generally not considered by candidates. An answer of 3.4 hours was common as candidates took the beginning and end values on the graph without realising that the isotope had decayed to background levels by this stage.
- (c) The idea of the half-life being independent of temperature was generally understood. For the second part of the question, many candidates stated that there was also no change, but this cannot be the case for a quantity that is random.

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 confuse are atom, molecule and nucleus; heat and temperature; 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.
- Candidates are encouraged to consider whether their answers to numerical questions make sense. Identifying that an answer cannot possibly have a particular order of magnitude (such as a speed greater than the speed of light) or be outside a particular range (such as a p.d. in a circuit greater than the supply p.d.) is often a good way of determining that a mistake might have been made.
- 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.

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.

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) The relationship between gravitational force, masses and distance between the masses was generally well-known. Some candidates who may have known the law were careless in their description of it, in missing out key words like 'product', 'inversely' or 'squared'. The fact that the law applies to the force between point masses was also known by a good proportion of candidates.
- (b) Most candidates knew that the starting point for this derivation was to equate gravitational and centripetal forces, and those who took care over their use of symbols were able to complete the derivation well. The main problem came for candidates who attempted to use the same symbol for the radius of Jupiter and for the radius of Io's orbit. These candidates inevitably found themselves ending up with algebra that did not lead to the required formula. The strongest candidates went straight to using nR for the radius of the orbit in the starting equation, and for candidates who adopted this approach the algebra could be completed straightforwardly in a few lines.

- (c) (i) Having derived the relevant equation in (b), candidates were here expected to use it by substituting the given values. Many were able to do this successfully. Of those who found the question more challenging, the main difficulty was the realisation that n is the ratio of the two distances given. Some other common mistakes were in the unit conversion of T from hours to seconds and in remembering to square T and/or cube r .
- (ii) Having deduced a value of density to be approximately one fifth of the density of the Earth, candidates were asked to suggest a possible composition of Jupiter. Some did not answer the question, instead just making comment on the relative values. Candidates are always encouraged to consider whether their answers to numerical questions are reasonable, and this question provided a good example of this.

Question 2

- (a) Most candidates realised that specific latent heat is to do with the energy needed to cause a change of state. The ratio of energy per unit mass was often missing, or expressed so that the ratio was not clear. The change of state aspect was often not qualified as being at constant temperature. A significant minority of candidates attempted to give a definition of specific heat capacity rather than specific latent heat.
- (b) (i) Many candidates found this question challenging, often missing the key word 'where' in the question. In **part 1**, some candidates were able to state that work is done on the atmosphere, but many talked about the beaker on the balance or switching on the circuit. Answers to **part 2** were often confused, with many realising that it is the internal energy of the water that increases but then associating this with a temperature rise rather than with the change of state that is taking place.
- (ii) Many good answers were seen to this question from more able candidates. Those who found it difficult did not appear familiar with the use of two sets of data to allow for heat loss. Answers based on one set of data were common, and a significant proportion of candidates either ignored time or carried out calculations based on energy = power/time. Another common approach was to use the difference in the current readings and the difference in the p.d. readings. Power-of-ten errors were rare in this question, and many candidates correctly used the mass in grams to find a value for specific latent heat in J g^{-1} .

Question 3

- (a) (i) Most candidates were able to define the radian as an angle subtended by an arc length equal to radius. Some gave this in terms of equal stated distances, such as 1 m. Fewer candidates were able to qualify that the angle in question relates to the centre or sector of a circle. A small number of candidates misread the question and gave a definition of angle in radians rather than the definition of one radian.
- (ii) A large proportion of candidates found it difficult to give a correct answer. Most answers were themselves definitions of frequency. Some candidates missed the simple harmonic motion context of the question and gave an answer relevant to circular motion (such as 'angular displacement per unit time'). In the context of simple harmonic motion, this answer is not correct (as angular frequency is not, for example, the angular displacement of a pendulum per unit time).
- (b) (i) There were many excellent definitions of the characteristic properties of simple harmonic motion that could not be given credit because they did not answer the question that was asked. In addressing the requirement to 'explain how the equation shows' (that the load is undergoing simple harmonic motion), candidates were expected to relate the fact that c/ML^3 is constant to acceleration being proportional to displacement, and they needed to relate the minus sign to acceleration and displacement being in opposite directions. Many candidates were able to do one of these, but very few did both.
- (ii) Those candidates who knew the defining equation of simple harmonic motion $a = -\omega^2 x$ were able to equate it with the expression given to deduce that $\omega^2 = c/ML^3$, and many candidates were thus able to answer the question correctly. Common mistakes were to forget to square ω , to conflate ω with frequency, or to forget to cube L . Power-of-ten errors in the unit conversions of M and L were comparatively rare.

Question 4

- (a) The word 'generation' was emboldened in the question, but many candidates gave descriptions of the use of ultrasound in medical diagnosis that could not be given credit. It is important that candidates read the question carefully and give an answer that addresses what is being asked.

Of those who did answer the question asked, most were able to gain credit for discussing the effect of applying an alternating voltage to a quartz crystal (in making it vibrate). Fewer were able to articulate why this is the case (in that a p.d. causes the crystal to distort). Credit was often not awarded as a result of imprecise use of language, such as talking about the 'frequency of vibration of the crystal' rather than the 'natural frequency of the crystal'. Only a minority of candidates explained that ultrasound is emitted because the natural frequency of the crystal is in the ultrasound range.

- (b) The answers of many candidates revealed that they did not understand ultrasound imaging. Many mentioned less attenuation and deeper penetration, and were unaware that there is very little absorption of ultrasound by soft tissue. Others discussed medical treatment rather than diagnosis. The strongest candidates realised that smaller wavelengths will result in a greater ability to resolve smaller structures.

Question 5

- (a) Most candidates were able to read the values from Fig. 5.1 correctly, but a large proportion of candidates found the binary conversion difficult. For those candidates who could do the binary conversion, a common mistake was to round the 0.8 ms reading to the nearest whole number of volts (hence converting to 0110) rather than realising that the process ignores part-voltages and truncates the value.
- (b) There were many good answers to this question, with the vast majority of candidates realising that the graph is stepped at 0.2 ms intervals. Common errors in the levels were to skip a level (such as starting with 8 rather than 0) and to display the penultimate level as 6 rather than 5.
- (c) This question was less well-answered by many candidates, with many omitting to mention the reduction in step height and many giving vague descriptions of a 'better' or 'clearer' signal. A minority of candidates were able to articulate that the reproduction of the input signal is more accurate or that the output signal represents the input signal more closely.

Question 6

- (a) Candidates were expected to comment that the field lines are perpendicular to the surface of the sphere and that, when extended back into the sphere, they appear to meet at the centre. Many candidates were not awarded credit because their answers conveyed the idea that there are field lines inside the sphere. Others contradicted themselves by stating that the electric field outside the sphere is both radial and uniform.
- (b)(i) This question was well answered by many candidates. There were several different possible approaches, and all were used to good effect by candidates. The most common errors were power-of-ten errors in taking readings of V and/or x from the graph. Others arrived at the correct answer but gave it to only one significant figure where a minimum of two was expected.
- (ii) Most candidates were able to deduce the radius of the sphere from the graph. Explanations were less successful, and most candidates tried to describe in words the trend of the graph. Of those who did address the properties of the field inside the sphere, there were many who successfully stated that the potential is constant. A small number of candidates confused potential with field, stating either that the potential is zero or that there is a constant electric field. This is another good example of the importance of using the correct technical terminology accurately.

Question 7

- (a)(i) This question was generally well answered, with most candidates stating that feedback is the return of part (or all) of the output to the input of the amplifier. Fewer candidates identified that what is being fed back is a voltage.

- (ii) Many candidates demonstrated a good knowledge of the benefits of negative feedback and received full credit. A common mistake was to just list the properties of an ideal op-amp. Some candidates correctly identified that negative feedback reduced the gain but then thought that this was a benefit in itself. Candidates should be encouraged to give the required number of answers and not to provide more than the required number.
- (b) (i) 1. The calculation of the gain was generally well done with most candidates knowing the definition of gain. Some incorrectly gave a unit (usually V) with it, and others used the supply voltage rather than the potential at point P as the input potential.
2. Most candidates found this part far more challenging, with only a small proportion of candidates knowing the formula for the gain of the non-inverting amplifier and able to substitute the resistance values correctly. Common mistakes were to use the inverting amplifier formula or to substitute the resistance values the wrong way around.
- (ii) Many candidates found it hard to express their reasoning, with most stating that the amplifier is saturated without any justification. The strongest candidates successfully calculated that, in the absence of saturation, the output potential would be 5.1 V and stated that, therefore, the amplifier saturates with an output of 5.0 V.

Question 8

- (a) (i) This question was well answered by the majority of candidates.
- (ii) There were two aspects to this question that candidates needed to explain. Firstly, why is a voltage developed and, secondly, why is that voltage constant? The second part cannot be adequately explained without addressing the first part, but some candidates focused purely on the 'constant' part of the question. These candidates confined their answers to analysing the Hall voltage equation and pointing out that all the quantities within it are constant.

Most candidates did attempt to explain why the voltage is developed, but often began their narrative half-way through the explanation. It might be that the existence of a current normal to a magnetic field resulting in a force being exerted on charge carriers normal to their motion was considered too obvious by some for them to think of writing it, but this is an intrinsic part of the explanation. Many candidates were able to give some sort of account of charge separation leading to the setting up of an electric field across the faces. The strongest candidates were able to explain that the voltage becomes constant when the electric and magnetic forces become equal, although some used incorrect terminology and referred to equal fields rather than equal forces.

The most common fundamental misconception of the mechanism by which the Hall voltage is set up was that it is something to do with electromagnetic induction. Many of the candidates who found this question difficult thought that an e.m.f. was induced because the current in the slice cut the magnetic flux through it.

- (b) Candidates found this question difficult, with most stating that the metal produces the higher voltage for a variety of given reasons. Some of these reasons were to do with lower resistance or higher current, but a good number of these candidates were aware that metals contain a greater number density of free electrons, mistakenly leading to a conclusion that this results in a higher Hall voltage. Of the candidates who did know the correct answer, some candidates gave an inaccurate or incomplete definition of n .

Question 9

- (a) This question was well answered by many candidates. Most knew that a field is a region of space where a force is exerted on a particle. Some candidates were not awarded credit because they confined their answers to a particular type of field rather than keeping the answer generic in nature.
- (b) There is an important point to be made about the use of diagrams by candidates to support a descriptive answer. A diagram is of no use unless it is adequately labelled. Many diagrams were well drawn by candidates who had clearly taken a lot of care, but there were not enough labels to show what the candidate intended each part of the diagram to represent. The use of diagrams is encouraged but, to be of any benefit in supporting the answer to this question, the magnetic field lines, the electric field lines and the direction of motion of the particles needed to be clearly

labelled. Where it is intended to convey from a diagram that lines are perpendicular to each other, the right-angle needs to be labelled.

Of candidates who were awarded credit, most were able to convey that the electric and magnetic particles act in opposite directions. Fewer went into enough details of the set-up (i.e. fields perpendicular to each other and velocity of the particle perpendicular to both fields). To gain full credit, candidates needed to make a link between the forces being equal and velocity selection, and most candidates found it difficult to put these two elements together. Some implied that the forces are equal for all particles, regardless of velocity. Others quoted the formula ($Eq = Bqv$) leading to velocity selection, but did not explain that this formula comes from the two forces being equal. Some others, as with **8(a)(ii)**, talked about the fields being equal rather than the forces.

- (c) Some candidates could not be given credit because they did not label the lines, so it was impossible for the Examiner to know which line was intended as the answer to which part.

In (i), few candidates realised that the particle with an unchanged velocity will remain undeviated. More candidates were able to score credit in (ii), with most able to deduce the direction of deflection correctly. Candidates generally found it difficult to draw a smooth curve that was continuous with the incident direction of travel.

Question 10

- (a) Less able candidates often did not know where to begin, and for these candidates there was a lot of guesswork. Some candidates did not mark the threshold wavelength on the graph and could not be awarded full credit. Of the stronger candidates, most realised that E_{MAX} is zero at the threshold wavelength. After that, many candidates demonstrated confusion with the E_{MAX} –frequency graph and drew straight lines with positive gradients. The strongest candidates realised that the threshold wavelength is the maximum wavelength that causes photoemission and so drew lines where E_{MAX} increases as wavelength decreases. Only a small minority deduced that there is an inverse relationship between the two quantities resulting in the shape being a concave curve.
- (b) Most candidates do know that de Broglie wavelength and momentum are related by the equation $\lambda = h/p$, but they found it difficult to show this on a graph. There were many straight lines (either of negative gradient or of positive gradient through the origin). Of those who did attempt to draw the required concave curve, many showed a line that touched an axis or became horizontal and/or vertical at the two ends.

Question 11

- (a) (i) This was generally well answered, with most candidates circling the correct two diodes. Some candidates circled the wrong two, but the most common mistake was to circle only one diode.
- (ii) This is another question that was answered correctly by most candidates. Some contradicted themselves by indicating both + and – signs at both terminals.
- (b) (i) Most candidates were able to deduce that the r.m.s. p.d. is the peak p.d. divided by $\sqrt{2}$ and to reach an answer of either 3.96 V or 4.0 V. A few gave the answer to an insufficient number of significant figures, but the most common mistake was to give the peak p.d. (5.6 V) as the r.m.s. p.d.
- (ii) Most candidates found this question challenging. Many were able to use the 380 figure correctly to deduce that the frequency of the original a.c. potential difference is 60.5 Hz. However, most candidates stopped there and did not appreciate that the rectified p.d. reaches its peak value twice per cycle of the original unrectified a.c. potential difference.
- (c) (i) There were many good attempts at this question. Candidates had quite a lot to do and consider for full credit, but most candidates received at least partial credit. Most realised roughly what effect the smoothing has on the shape of the rectified potential difference and were given credit for keeping the peak value of the p.d. the same. A common conceptual mistake was to use a minimum p.d. of 1.6 V (rather than the 4.0 V that a 1.6 V ripple will cause). After that, mistakes were often due to carelessness rather than misunderstanding the physics. Many of the decay stages of the graph were shown as convex curves or did not start/end at the correct places on the unsmoothed line.

Many candidates omitted to include the charging phases along the dotted line back to the peak p.d. and the start of the next cycle.

- (ii) Many candidates found this a challenging question, with few appreciating that smoothing leads to an increase in the r.m.s. potential difference and hence an increase in mean power dissipated. Most thought that the mean power would decrease, and gave a variety of incorrect reasons to support this claim.

Question 12

- (a) (i) The key idea of emission from an unstable nucleus was absent from the answers of most candidates. Of those that did mention emissions from a nucleus, many were insufficiently precise in their description of what is emitted. A significant minority of candidates were confused between radioactivity and nuclear fission.
- (ii) Most candidates gave a definition of either half-life or activity in their answers to this question. Of those who did know that decay constant is to do with the probability of decay, many referred to the decay of something vague such as 'the material' or 'the substance' rather than a nucleus. A minority of candidates gave a fully correct answer including the required 'per unit time'.
- (b) Most candidates found this question challenging, with only a small number appreciating that the emitted beta particle has to share the energy of the disintegration with the emitted antineutrino. Two misconceptions were very common. Many candidates thought that the beta particles were being emitted from the electron orbitals and that the variation of energy was therefore to do with electrons being emitted from varying states of excitation. Other candidates confused beta decay with the photoelectric effect and talked about work needing to be done for the electron to reach the surface of the nucleus before being emitted.
- (c) (i) Most candidates received credit for knowing that $A = \lambda N$. Many were also able correctly to deduce the value of N . The conversion of λ from day^{-1} to s^{-1} proved problematic for many candidates. Some did not attempt a conversion, thus reaching an answer of 4.7×10^{11} . It is important to note that this could be a valid answer, if given with the correct unit. However, it cannot receive credit with the unit Bq.
- (ii) This was a difficult question at the end of the paper, and many of the more able candidates were awarded full credit. Many candidates made the calculation more awkward than it needed to be by taking an activity and working out $1/50$ of it so that they had two activities to substitute into the exponential equation. Few realised that all that was needed was to equate $\exp(-\lambda t)$ with $1/50$.

Some candidates who reached the correct answer were not awarded credit because of a careless error at the end, and it raises an important point of principle worth noting. In numerical questions, candidates are expected to round their answers and to express them to the appropriate number of significant figures at the end of a calculation. Rounding twice can introduce an arithmetic error into the final significant figure of the final answer such that it makes it incorrect. The required calculation yields an answer of 45.488 days, which is expected to be rounded to 2 significant figures to give 45 days. Some candidates rounded twice, first to 3 significant figures to give 45.5 days, and then again to 2 significant figures but now getting 46 days. It is important that candidates are encouraged to round once, to the correct number of significant figures, so as to avoid the introduction of unnecessary error into their answers.

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 confuse are atom, molecule and nucleus; heat and temperature; 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.
- Candidates are encouraged to consider whether their answers to numerical questions make sense. Identifying that an answer cannot possibly have a particular order of magnitude (such as a speed greater than the speed of light) or be outside a particular range (such as a p.d. in a circuit greater than the supply p.d.) is often a good way of determining that a mistake might have been made.
- 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.

General comments

Some weaker candidates find converting powers of ten and unit conversions troublesome. This year some candidates had problems converting MeV to J, km to m and mass numbers into kg.

The use of singular and plural terms can cause difficulty but can be important. For example, in **Question 9(a)**, candidates need to be clear whether they are referring to a single slice or to multiple slices.

Many candidates are better at calculations than they are at descriptive answers. Practice at questions from past exam papers might help candidates with this, as would paying careful attention to the mark schemes and Principal Examiner Reports for Teachers.

Very few candidates explain any mathematical substitutions they make, and this can make it unclear how the different lines in the candidate's working are related. Sometimes there is a scattering of formulae in the margin of the answer space. It is not possible to award credit for a list of unconnected formulae when a question asks candidates for a derivation. Candidates should be encouraged to state the formulae they use clearly.

Comments on specific questions

Question 1

- (a) (i) The most common misconception was that objects at different temperatures always have different amounts of internal energy.
- (ii) Candidates often did not realise that they needed to refer to thermometric/physical properties of materials.

- (b) A common incorrect suggestion was that the thermometers had different sensitivities. Many candidates wrote about the heat capacity of the thermometers being different and so took different times to show the correct temperature. Very few responses showed that candidates realised that the thermometric properties may not behave linearly.
- (c) (i) The calculation was generally well executed. A significant number of candidates made life difficult by adding and then subtracting 273 from the temperature in their calculations.
- (ii) The line on the graph was frequently correct and the calculation was generally well executed.

Question 2

- (a) Candidates found this question difficult. Most answered with reference to angular velocity and circular motion rather than angular frequency and simple harmonic motion. If a formula is used to define a quantity, then candidates need to define the terms in their formula in order to receive credit.
- (b) (i) Even the more able candidates found it difficult to determine these two displacements. There was a lot of information in the question before the answer lines and successful candidates would have read the information carefully before considering the graph. These questions were asked to help the candidates use the correct displacement in the calculation in (iii).
- (ii) Few candidates mentioned the fact that the equilibrium position was at $a = 0$ and $s = 2.0$ cm. Whilst most candidates knew that the two necessary conditions for simple harmonic motion were proportionality with acceleration and displacement in opposite directions, only the stronger candidates related these conditions to the straight line and its negative gradient.
- (iii) Stronger candidates generally arrived at the correct value. The weaker candidates tended to use coordinates directly from the graph without subtracting 2.0 cm from the value of the displacement, which was needed before using the formula $a = (-)\omega^2 x$. A common mistake was to forget to convert a value in centimetres into metres. A few candidates used the gradient rather than the reciprocal of the gradient.

Question 3

- (a) Most candidates knew this definition, but some mixed it up with gravitational potential and gravitational potential energy. The 'per' is required to explain the division of the force by the mass. Candidates should avoid writing 'per kg' as units should not be used in the definition of a quantity.
- (b) A common mistake amongst weaker candidates was not to compare the very small change in height h with the radius of the Earth. Of the candidates who did make a valid comparison, the strongest correctly stated that either $g = GM/R^2 \approx GM/(R + h)^2$ or stated that, for such comparatively small changes in h , the field lines are almost parallel and the field would effectively be constant.
- (c) Answers to this calculation were good and usually well presented. Candidates have seen this type of question before and they clearly understood what was required. Some candidates did not explain where the centripetal force arises. In addition, there were some mistakes of forgetting to square or cube numbers and forgetting to change into SI units.

Question 4

- (a) Many weaker candidates listed the advantages of the coaxial cable over other types of cable, rather than the function of the copper braid.
- (b) Weaker candidates performed better on this part of the question. The most common correct suggestions involved smaller bandwidth and increased interference. Many candidates referred to the security of the signal, but the context of the question was a television aerial, so this suggestion did not gain credit.

- (c) Most candidates could calculate a value of the attenuation of 2.66 dB and could state that attenuation was given by an expression of the form $-10 \lg (P_2/P_1)$. Weaker candidates tended to arrive at either $P_{\text{OUT}}/P_{\text{IN}} = 1.85$ or $P_{\text{IN}}/P_{\text{OUT}} = 0.54$, because they had used either $10 \lg (P_{\text{OUT}}/P_{\text{IN}})$ or $-10 \lg (P_{\text{IN}}/P_{\text{OUT}})$. The strongest candidates went on to calculate the fractional loss correctly.

Question 5

- (a) (i) Most candidates stated Coulomb's law correctly. Some candidates referred to the product of two masses in the statement of the law. Candidates should be encouraged to re-read their answers in order to avoid mistakes like this.
- (ii) Most candidates could draw a downwards curve on the graph of decreasing gradient. Some candidates did not gain credit because their curves did not start from (R, F_C) or did not pass the relevant points of $(2R, 0.25F_C)$ and $(4R, 0.06F_C)$.
- (b) This question discriminated well. Weaker candidates often copied the original line, or drew a reflection of it. More able candidates were able to use the gradient of the original line to get the line for the induced e.m.f. Only the strongest candidates noted the correct difference in magnitude of the two gradients between t_1 and t_2 , and t_3 and t_4 .

Question 6

- (a) (i) Most candidates knew how to calculate the capacitance of a combination of capacitors, although a common mistake was to use the formulae the wrong way around and end up with $3C/2$ instead of $2C/3$. Some candidates did not realise that the capacitors all had the same value of capacitance, and made life very difficult with a complicated method.
- (ii) Although 6 V was a very common answer, it wasn't always clear that the candidates knew how they had reached their answer and consequently credit could not be awarded for the explanation. The key to the explanation is the fact that the charge is the same on the single capacitor and the parallel combination.
- (b) Some candidates wrote that the two capacitors reached a voltage of 4.5 V. Of those candidates who correctly stated that the voltage across P would fall and that across Q would increase, only a limited number gave any valid explanation along the lines that capacitor P would discharge through the resistor R whilst at the same time capacitor Q would charge. Candidates often did not mention the final voltages of 0 V and 9 V once discharging or charging had occurred.

Question 7

- (a) (i) Candidates' explanations of the circuit's virtual earth were generally good. Most candidates would point out V^+ was connected directly to earth. All but the weakest candidates could explain that the op-amp's infinitely large gain would lead to saturation, although less able candidates tended not to state that, in order to avoid saturation, V^- must be equal or close to V^+ .
- (ii) Nearly all but the very weakest candidates could at least state that $\text{gain} = -R_2/R_1$. The majority of candidates made a reasonable attempt at deriving this expression. Only the more able candidates would preface their derivations by stating that the current in R_1 would equal the current in R_2 because the op-amp's input impedance is infinite.
- (b) This graph again discriminated well between candidates. Most candidates drew an inverted shape correctly and worked out that the gain of 4.5 would lead to a voltage of $4.5 \times 3 \text{ V} = 13.5 \text{ V}$. Many candidates did not take into account the fact that the op-amp had a supply voltage of $\pm 9 \text{ V}$ and so would saturate at 9 V. Of those who limited their output signal graphs to 9 V, about half drew both ends of the horizontal line occurring at correct times.

Question 8

- (a) The majority of candidates could do this correctly, giving four letters for each face (DERQ and CFSP). Some weaker candidates gave only two letters relating to a face and this was insufficient to identify the faces.
- (b)(i) This derivation proved fairly straightforward for most candidates, but some found it difficult to derive $V_H = Bvd$ because they used $F = BIL$, rather than $F = Bqv$.
- (ii) Most candidates, even if they had not derived it in (i), recalled the equation $V_H = Bvd$ as a starting point. The majority could introduce the formula $I = nAqv$ and reached $V_H = BId/nAq$. Weaker candidates tended not to explain why d/A became t in their expression.
- (c) Only the stronger candidates suggested that, as copper is a metal, the charge density n is very large and therefore V_H would be very small and difficult to detect. Most candidates tended to base their responses on the thickness of the slice and did not gain credit.

Question 9

- (a) There were some good responses. Weak responses were quite common, often because candidates confused the concepts of a slice and an image, and would refer to a slice of an image rather than an image of a slice. Also, weaker responses tended to lack a logical order and either go into too much detail (such as including detailed information about voxels) or include irrelevant details such as how X-rays are produced. Some of the best answers were often the briefest.
- (b) Many correct answers were given. A few candidates subtracted the background and then stopped. Candidates doing this might have been thinking logically, realising that the background should not be counted, but did not know how to proceed.

Question 10

- (a) Weaker candidates tended incorrectly to base their answers upon either back e.m.f. or upon eddy currents. Some introduced the idea that the root-mean-square current would be non-zero but then did not build on this concept to explain why the power dissipated would be non-zero.
- (b)(i) Most candidates realised that a high voltage meant a low current and that this meant less power loss, but they did not always say that the power remained constant.
- (ii) Most candidates realised that alternating voltages could be easily transformed, but not that transformers only worked with alternating current.

Question 11

- (a) Most candidates were able to state what is meant by a photon. A minority did not refer to energy.
- (b) These calculations were straightforward for those candidates who knew the formulae. There were some power of ten errors and some forgot to convert from eV into J.
- (c) This question was well answered. A fairly common power-of-ten mistake was to calculate the mass of the indium-123 nucleus in gram using $\text{mass} = 123/N_A$ and then forget to convert this into kilogram.

Question 12

- (a) Some candidates overlooked the statement that radiation is emitted in all directions and that the detector does not surround the source, and gave this as one of their reasons. Some weak responses were too vague to gain credit, such as 'the radiation does not reach the detector'.
- (b)(i) This was well answered by candidates. Some candidates explained that the curve showed exponential decay, which is a characteristic of radioactive decay but not of the randomness of radioactive decay.

- (ii) Most answers were mathematical rather than graphical. In answering this type of question, candidates should be encouraged to take more than one half-life and average. The fact that there was a background count or systematic error, which is clear when considering the count rate at later times, was generally not considered by candidates. An answer of 3.4 hours was common as candidates took the beginning and end values on the graph without realising that the isotope had decayed to background levels by this stage.
- (c) The idea of the half-life being independent of temperature was generally understood. For the second part of the question, many candidates stated that there was also no change, but this cannot be the case for a quantity that is random.

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Key messages

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

General comments

The majority of candidates completed the paper although a few candidates appeared to rush at the end of **Question 2**. There was a full range of marks for the paper with candidates tending to find **Question 2** slightly less difficult than **Question 1**. The majority of the scripts were clearly written. In general, graphs were well drawn with points and error bars easily identifiable.

In **Question 1**, circuit diagrams should use appropriate symbols. Candidates tend to find the methods of data collection and the additional detail sections harder than defining the problem and the method of analysis. 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. More able candidates appear to have experienced a practical course where the skills required for this paper are developed and practised. This is helpful when candidates are adding detail to their plans.

In **Question 2**, it is important that candidates present their mathematical working clearly. For full credit, there should be a statement of the equation used, substitution of numbers and the answer evaluated correctly. The working should be set out in a logical and readable manner.

Comments on specific questions

Question 1

Candidates should be encouraged to take time to read the question carefully before writing their answers. Stronger candidates often drafted the key points of the plan in pencil on page 2 of the question paper. Most candidates understood the basic requirements of the experiment, but many did not describe the design and laboratory procedure in sufficient detail.

Most candidates correctly identified the independent and dependent variables and quantities that needed to be kept constant. A large number of candidates were given credit for stating that the intensity of the light source needed to be kept constant, although a small but significant number of candidates used the word 'control' instead of 'constant'. It is important to identify quantities that need to be kept at a constant value for

the investigation to be valid. Many candidates stated temperature should be kept constant, which was not necessary in this investigation and did not gain credit.

Credit was awarded for a clearly labelled diagram. Diagrams should include the necessary pieces of apparatus set up as they would be used in the experiment. In this question, credit was awarded for indicating a method to support the light source above the LDR.

Candidates needed to draw a circuit diagram for a circuit to measure the resistance of the LDR. It is important that candidates use correct circuit symbols in their diagrams. The majority of candidates chose a method using a voltmeter and ammeter. A number of these circuits were incorrectly drawn, with common errors including putting voltmeters in series or not connecting the voltmeter across the LDR. A small number of candidates chose the simple way of connecting the LDR directly to an ohmmeter, although many of these candidates incorrectly included a cell in that circuit.

Credit was available for describing how the resistance could be determined. Candidates who chose the ohmmeter method for measuring resistance almost inevitably received credit. Those who drew a correct voltmeter-ammeter circuit generally made R the subject of the formula, and gave the equation as $R = V/I$. Candidates needed to define the symbols clearly and correctly. Some candidates confused the LDR circuit with the light source circuit.

Many candidates stated that a ruler would be used to determine the distance d . Other candidates drew a labelled metre rule fixed vertically with the distance d clearly indicated. Additional detail credit was available for clearly describing an appropriate method to ensure that the rule was vertical when making the measurement of d and for additional detail on making the measurement of d accurate, e.g. the use of fiducial markers or subtracting the height of the LDR from the reading on the rule.

Credit for stating an appropriate graph to draw was usually awarded—most candidates suggested R against d^2 . A few candidates rearranged the equation correctly but did not state what would be plotted on the axes. Others plotted a graph without identifying what would be plotted.

When stating how the results could prove the relationship, candidates are expected to state 'the relationship is valid if a straight line passing through the origin is observed' for a graph of R against d^2 . For logarithmic relationships, candidates needed to state the correct numerical gradient of the line. This mark can only be awarded from an appropriate graph.

Credit was available for explaining how K could be determined. This required K to be the subject of the equation that included the gradient. In the case of logarithmic graphs, K needed to be the subject of the equation that included the y -intercept. This mark can only be awarded from an appropriate graph.

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. In this experiment, many answers which were concerned with water, ranging from its density, temperature and purity, and the effects of electricity on the water, did not gain credit.

Credit was available for a safety precaution which required a clearly reasoned precaution relevant to the experiment. In this experiment, a safety precaution linked to either the bright, intense light source or the hot light source was required.

Other common creditworthy additional detail included performing the experiment in a dark room or shielding the LDR from background light and using a high intensity lamp. Some candidates drew a clear circuit diagram for the light source that included a rheostat and ammeter, and then explained that the rheostat would be adjusted to maintain a constant current to keep the intensity of the light source constant.

Question 2

- (a) Candidates were required to determine an expression for the gradient and y-intercept from the graph of $(T_1 - T_2)$ against x where T_1 and T_2 are the support forces and x is the distance of the load from force T_1 . This was generally well answered.
- (b) The table was completed well with the majority of candidates awarded full credit. Some candidates used an incorrect number of significant figures or made an incorrect calculation of the uncertainty. Candidates need to know that the absolute uncertainties are added when quantities are subtracted.
- (c) (i) Most of the candidates were awarded full credit for plotting the points and error bars. A common mistake was the drawing of large 'blobs' for the plotted points. Some candidates' error bars were not equal in length.
- (ii) The drawing of both the line of best fit and the worst acceptable line was good. Most candidates obtained credit for the line of best fit, but a significant number of candidates drew an imprecise worst acceptable line through the tops and bottoms of the chosen bars. Some candidates joined the first plotted point to the last plotted point, and this did not give the line of best fit. Care must be taken in drawing the line of best fit, balancing the position of the plotted points on each side of the line. Candidates should clearly indicate the lines drawn.
- (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 from the wrong line owing to unclear labelling of the lines. Candidates should be advised to take points from the line and not data points from the table.
- (iv) Many candidates were awarded full credit. Candidates were required to substitute points into $y = mx + c$. Common mistakes in calculating the uncertainty in the y-intercept were either to use the same coordinates as the line of best fit (this can be done only if the crossing point is used), or to use the gradient of the line of best fit. Evidence for the value of the uncertainty was required by subtraction of the y-intercepts of the line of best fit and the worst acceptable line. Directly reading the value of the intercept from the y-axis of the graph was incorrect as there was a false origin.
- (d) (i) Candidates were required to determine values for m and s . Candidates were also required to include units for the quantities and give their answers to an appropriate number of significant figures. It is highly desirable that candidates set out their working in a clear and logical manner, substituting numerical values for the known quantities in equations.

Candidates who had correctly stated the expressions for gradient and intercept in (a) were generally successful. Common mistakes involved incorrect or missing units, the wrong power of ten and an inappropriate number of significant figures in the final answer. Some candidates did not show the necessary working to demonstrate they understood the physics involved. Stronger candidates clearly indicated what their values of gradient and y-intercept represented.

- (ii) Showing clear and logical working is essential for this part. It was well answered, particularly by candidates who used the method of adding percentage uncertainties of the gradient and intercept. Those candidates who attempted to calculate the maximum and minimum values for s tended to make more mistakes by using incorrect combinations of maximum and minimum values.

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Key messages

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

General comments

The majority of candidates completed the paper although a few candidates appeared to rush at the end of **Question 2**. There was a full range of marks for the paper with candidates tending to find **Question 2** slightly less difficult than **Question 1**. The majority of the scripts were clearly written. In general, graphs were well drawn with points and error bars easily identifiable.

In **Question 1**, circuit diagrams should use appropriate symbols. Candidates tend to find the methods of data collection and the additional detail sections harder than defining the problem and the method of analysis. 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. More able candidates appear to have experienced a practical course where the skills required for this paper are developed and practised. This is helpful when candidates are adding detail to their plans.

In **Question 2**, it is important that candidates present their mathematical working clearly. For full credit, there should be a statement of the equation used, substitution of numbers and the answer evaluated correctly. The working should be set out in a logical and readable manner.

Comments on specific questions

Question 1

Candidates should be encouraged to take time to read the question carefully before writing their answers. Stronger candidates often drafted the key points of the plan in pencil on page 2 of the question paper. Most candidates understood the basic requirements of the experiment, but many did not describe the design and laboratory procedure in sufficient detail.

Credit is available for identifying the independent and dependent variables and identifying quantities that need to be kept constant. Most candidates identified the independent and dependent variables. A large number of candidates correctly stated that the current in coil P needed to be kept constant, although a small

but significant number of candidates used the word 'control' instead of 'constant'. It is important to identify quantities that need to be kept at a constant value for the investigation to be valid.

Candidates were given credit for a correct, labelled diagram indicating how the two coils were to be supported. Some candidates drew the coils vertically above each other, and this was awarded credit.

Candidates needed to draw circuit diagrams connected to each of the two coils, with correct circuit symbols. Many candidates could not be awarded credit for the circuit because they drew one circuit diagram which connected both coils.

Many candidates stated that a ruler would be used to determine the distance x . Other candidates drew a labelled metre rule fixed parallel to the axis of the coils with the distance x clearly indicated. There was credit available for determining the distance x from the centre of each coil, but it was not often awarded since candidates often determined the radial centre but not the width of the coils.

Credit was available for the analysis of data. Most candidates correctly suggested plotting a graph of $\ln V$ against x , although a significant number of weaker candidates incorrectly suggested plotting V against x . Graphs of $\log V$ against x or $\lg V$ against x also gained credit. Plotting $\ln(V/V_0)$ was not given credit because V_0 could not be physically determined. When stating how the results could prove the relationship, candidates are expected to state 'the relationship is valid if a straight line is observed' for an appropriate logarithmic graph. Candidates also needed to explain how k could be determined from the graph. This required k to be the subject of the equation that included the gradient. This mark can only be awarded from an appropriate graph.

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. In this experiment, a safety precaution linked to the hot coils was required.

Other common creditworthy additional detail included using a large current in coil P or the use of an iron core. Candidates could also describe keeping the frequency of the signal generator constant. Some candidates drew a clear circuit diagram for coil P that included a rheostat and ammeter and then explained that the rheostat would be adjusted to maintain a constant current so as to keep the maximum magnetic field constant. A large number of candidates gained credit for the additional detail of a full logarithmic equation using natural logarithms. If 'log' was used, it was expected that there would be a 'log e ' term for credit to be given.

Question 2

- (a) Candidates were required to determine an expression for the gradient from a graph of M against $1/n^2$. This was generally answered well. When errors did occur, it was often with some confusion over the terms that needed to be squared.
- (b) The majority of candidates were awarded full credit. Candidates who recorded $1/n^2$ as a fraction did not gain credit. Credit for $1/n^2$ was also not gained when candidates incorrectly rounded their data. Although n appeared to have one significant figure, n is an integer and thus $1/n^2$ could have been given to more than one significant figure. Some candidates incorrectly assumed that the absolute uncertainty in the mass values was 0.1.
- (c) (i) Most of the candidates were awarded full credit for plotting the points and error bars. A common mistake was the drawing of large 'blobs' for the plotted points. Some candidates' error bars were not equal in length.
- (ii) There has been an improvement in the drawing of lines, but only a small proportion of candidates were awarded full credit. A large number of candidates joined the first plotted point to the last plotted point, and this did not give the line of best fit. Care must be taken in drawing the line of best fit, balancing the position of the plotted points on each side of the line. Candidates who did not gain credit for the worst acceptable line were usually imprecise in drawing the line through the tops and bottoms of the chosen bars. Candidates should clearly indicate the lines drawn.

- (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 from the wrong line owing to unclear labelling of the lines. Candidates should be advised to take points from the line and not data points from the table. There were some errors in reading the x-axis scale, e.g. sometimes 0.16 (which is beyond the axis) was used instead of 0.106.

- (d)(i) Candidates were required to determine a value of the mass per unit length μ from the expression for the gradient. Candidates were also required to include an appropriate unit for μ and give their answer to an appropriate number of significant figures.

Candidates who had correctly stated the expression for gradient in (a) were generally successful, although a significant number of candidates did not evaluate the expression correctly. The majority of candidates gained credit for giving their answer to an appropriate number of significant figures. For full credit, candidates needed to determine μ in a given range and with an appropriate unit, e.g. g m^{-1} or kg m^{-1} . Combinations of units involving both s and Hz were not credited; stronger candidates clearly worked out the units for mass per unit length. The most successful candidates clearly showed their working for this question.

- (ii) Showing clear and logical working is essential for this part. It was generally well answered, particularly by candidates who used the method of adding percentage uncertainties. Some candidates incorrectly subtracted fractional uncertainties. Another common difficulty was not being able to deal with squared terms correctly, i.e. not realising that the fractional uncertainty in f^2 is twice the fractional uncertainty in f . The candidates who attempted to calculate the maximum and minimum values for μ tended to make more mistakes by using incorrect combinations of maximum and minimum values.

- (e) Again, clear, logical working was required for this part. Many candidates did not allow for μ being determined in g m^{-1} in (d)(i) and thus gave an answer that was incorrect by a factor of 1000. Other candidates found it difficult to deal with the squared terms. For full credit, clear and logical working was needed. It was expected that appropriate equations would be used with substitution of data. Some candidates did not use the value of 180 Hz, and some other candidates correctly worked out the fractional uncertainty but did not determine the absolute uncertainty.

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Credit was available for explaining how K could be determined. This required K to be the subject of the equation that included the gradient. In the case of logarithmic graphs, K needed to be the subject of the equation that included the y -intercept. This mark can only be awarded from an appropriate graph.

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Question 2

- (a) Candidates were required to determine an expression for the gradient and y-intercept from the graph of $(T_1 - T_2)$ against x where T_1 and T_2 are the support forces and x is the distance of the load from force T_1 . This was generally well answered.
- (b) The table was completed well with the majority of candidates awarded full credit. Some candidates used an incorrect number of significant figures or made an incorrect calculation of the uncertainty. Candidates need to know that the absolute uncertainties are added when quantities are subtracted.
- (c) (i) Most of the candidates were awarded full credit for plotting the points and error bars. A common mistake was the drawing of large 'blobs' for the plotted points. Some candidates' error bars were not equal in length.
- (ii) The drawing of both the line of best fit and the worst acceptable line was good. Most candidates obtained credit for the line of best fit, but a significant number of candidates drew an imprecise worst acceptable line through the tops and bottoms of the chosen bars. Some candidates joined the first plotted point to the last plotted point, and this did not give the line of best fit. Care must be taken in drawing the line of best fit, balancing the position of the plotted points on each side of the line. Candidates should clearly indicate the lines drawn.
- (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 from the wrong line owing to unclear labelling of the lines. Candidates should be advised to take points from the line and not data points from the table.
- (iv) Many candidates were awarded full credit. Candidates were required to substitute points into $y = mx + c$. Common mistakes in calculating the uncertainty in the y-intercept were either to use the same coordinates as the line of best fit (this can be done only if the crossing point is used), or to use the gradient of the line of best fit. Evidence for the value of the uncertainty was required by subtraction of the y-intercepts of the line of best fit and the worst acceptable line. Directly reading the value of the intercept from the y-axis of the graph was incorrect as there was a false origin.
- (d) (i) Candidates were required to determine values for m and s . Candidates were also required to include units for the quantities and give their answers to an appropriate number of significant figures. It is highly desirable that candidates set out their working in a clear and logical manner, substituting numerical values for the known quantities in equations.

Candidates who had correctly stated the expressions for gradient and intercept in (a) were generally successful. Common mistakes involved incorrect or missing units, the wrong power of ten and an inappropriate number of significant figures in the final answer. Some candidates did not show the necessary working to demonstrate they understood the physics involved. Stronger candidates clearly indicated what their values of gradient and y-intercept represented.

- (ii) Showing clear and logical working is essential for this part. It was well answered, particularly by candidates who used the method of adding percentage uncertainties of the gradient and intercept. Those candidates who attempted to calculate the maximum and minimum values for s tended to make more mistakes by using incorrect combinations of maximum and minimum values.