PHYSICS

	Paper 9702/11
	Multiple Choice

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

Comments on specific questions

Question 2

This type of question is most easily answered by sketching a diagram. Considering components in the initial direction of motion, $(v/2)\cos\theta = v/4$, so $\cos\theta = 0.5$ and $\theta = 60°$.

Question 5

The simplest approach is to realise that, at maximum height, the velocity of the ball must be zero. Weaker candidates often chose **B**, which is the point at which the ball is leaving the surface immediately after the first bounce.

Question 7

Many candidates chose **C**. The force is constant, so **C** would be correct if the mass was constant. However, the mass is decreasing and so the acceleration is increasing.

Question 11

The gravitational field and force are downwards, so the electric force must be upwards. A negative charge in a downward electrical field will have an upward force on it, making **A** correct. Many candidates chose **B** but there will be a downward electric force on this particle.

Question 15

Weaker candidates often chose **C**. There is no change to the kinetic energy because the man is climbing at a steady speed.

Question 25

Care is always required with Doppler effect questions. Candidates needed $336 \times 400/(336-30)$ [= 439] and $336 \times 400/(336+30)$ [= 367]. The difference is 72 Hz.

Question 30

A common incorrect answer was **C**, which candidates obtained by using the distance moved by the charge. However, these candidates did not consider the direction of the force on the charge. The force on the charge is radially outwards from the centre so the distance moved in the direction of the force is zero, and no work is done.

Question 35

Candidates found this question difficult. The extra resistor in parallel reduces the total resistance of the circuit and so the current increases. With more current through the cell, there is a higher potential difference across its internal resistance, so the potential difference across R decreases.

PHYSICS

Paper 9702/12
Multiple Choice

Question Number	Key	Question Number	Key
1	B	21	B
2	A	22	C
3	D	23	B
4	C	24	A
5	B	25	D
6	A	26	B
7	C	27	D
8	B	28	B
9	C	29	B
10	A	30	C
11	C	31	C
12	D	32	A
13	D	33	A
14	C	34	C
15	B	35	A
16	C	36	B
17	C	37	B
18	A	38	A
19	A	39	B
20	D	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, $4.6 \, \mathrm{m\,s^{-1}}$ and $4.6 \, \mathrm{km\,s^{-1}}$ 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 9**, **10**, **21** and **33** difficult. **Questions 13**, **20**, **22**, **30** and **39** were relatively straightforward.

Comments on specific questions

Question 2

To answer this type of question, candidates should be encouraged to write on their question papers. Here a vertical line, about $\frac{3}{4}$ of the length of the 4 N line, would clearly show that the resultant is given by **A**. Many candidates incorrectly chose **C** which does not have the correct direction.

Question 4

This was a challenging question but stronger candidates were able to find the correct answer. Candidates needed to realise that the percentage uncertainties in both electrical measurements and all three dimensions are added.

Question 6

A must be correct here because the ball ends up at the original level. It cannot therefore be travelling faster at the end than it was travelling at the start, so **C** cannot be correct.

Question 9

This question showed a misconception about the idea of 'action and reaction' forces. The two forces in each pair must be <u>the same type of force</u> and <u>act on different bodies</u>. When an object is resting on a table, the weight of the object is equal and opposite to the contact force from the table but this is **not** an action and reaction pair. The weight of the object is a gravitational force and the support force is an electrical contact force.

The equal and opposite reaction force to the weight of the object is the force the object pulls upwards on the Earth. The other pair of equal and opposite forces is the force the table exerts upwards on the object and the force the object exerts downwards on the table. In each pair, the forces must act on different bodies.

Question 10

Candidates found this question difficult. Many candidates chose **B**. It is correct that the liquid pressure is less at smaller depth, but the difference in pressure between the bottom and top of the cylinder is the same at position P and position Q, so the tension in the cord at P and Q will be the same.

Question 21

The work done in stretching the rubber band along the path OPQ is the area under the curve (area X + area Y), so **B** is the correct answer. Amongst weaker candidates, **C** was a common incorrect answer.

Question 33

The resistance calculated using $R = V^2/P$ is the resistance at operating temperature (576 Ω). Weaker candidates often chose **B** as the final answer without considering that the room temperature resistance must be less by a factor of 16.

Question 36

The physics of this question is straightforward but it requires careful working, and it is easy to make a mistake. The most common incorrect answer was **D**, which has a resistance of 4.8 Ω. The resistance is slightly greater for **B** at 5 Ω.

PHYSICS

| Paper 9702/13 |
| Multiple Choice |

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

Comments on specific questions

Question 9

Many weaker candidates chose **A**. These candidates misunderstood the vector nature of momentum, and determined the change in momentum using $2.0 \times (4.0 - 2.8)$ instead of $2.0 \times (4.0 - (-2.8))$.

Question 12

The question states that the bubble is moving at constant velocity, so there is no resultant force. A common misconception is that there is a net upward force because the bubble is moving upwards, and this led some candidates to choose the incorrect answer **B**.

Question 13

Many candidates chose **D**. If forces P and R were equal, there would be no upthrust on the sphere. The pressure in the water is greater at R than at P, so **A** is correct.

Question 22

This type of question is best answered by sketching on the question paper. If candidates sketch the position of the wave slightly later in time (i.e. shifted to the right) they will see that the largest upward change in displacement occurs at a distance of $0.5\,\text{m}$. Many candidates chose **C**, which is a position at which there is maximum downward velocity.

Question 27

If there are more lines per millimetre, the angle of diffraction increases. The value of d in the equation $n\lambda = d\sin\theta$ is reduced and so the value of $\sin\theta$ (and therefore θ) increases. The angle between the first and second orders of diffraction increases and another effect is a reduction in the number of orders of diffraction visible.

Question 28

Many candidates gave either **A** or **B** as the answer. These candidates were thinking of the positions of the bright fringes but the question asked about **dark** fringes, i.e. the positions of destructive interference. Option **D** is not correct because the first dark fringe ($n = 1$) occurs when the path difference is $\lambda/2$.

Question 33

For a cube with sides of length a, the resistance ($\rho l/A$) is $\rho a/a^2 = \rho/a$. For sides of length $3a$, the resistance must be $\rho/3a$.

Question 34

Candidates could have thought about their everyday experience when answering this question, but all the information they needed was given. If the e.m.f. decreases, then the intercept on the graph decreases. If the internal resistance increases, then the gradient of the graph becomes steeper. Weaker candidates often chose **A**, which shows the correct increase in internal resistance but does not show a decrease in e.m.f.

Question 38

This question required recall of properties of α-particles. Most candidates knew the correct charge and so did not choose **C**. Some candidates chose **A**, but the continuous distribution of energies is a property of β-particles rather than α-particles.

PHYSICS

Paper 9702/21
AS Level Structured Questions

Key messages

- Candidates should carefully use the appropriate physics terms when producing definitions, written explanations or descriptions. A missing key word or an incorrect word may prevent the candidate from being awarded credit.

- In 'show that' questions, candidates should methodically write down each step in their calculation leading to the final answer. Well-presented calculations enable candidates to check that the solution is correct and clearly demonstrate that the answer they obtain is the value given in the question.

- In numerical solutions, candidates sometimes show their working with an expression that does not have a subject. There are times when the subject changes because of changes made to the expression. If the final answer is incorrect then credit for this type of working often cannot be awarded. Candidates should be encouraged always to provide a subject of any equation. Rearrangement of equations is only possible with the inclusion of the subject.

General comments

Candidates should be encouraged to read the question carefully to ensure their answers are appropriate in context, rather than simply attempting to recall memorised extracts.

In **Question 6**, many candidates were unable to apply their understanding of drift velocity to a circuit containing wires of different cross-sectional areas. Most candidates find it difficult to understand how circuits operate when they incorporate cells that are connected in parallel.

There was no evidence that candidates were short of time to finish their answers.

Comments on specific questions

Question 1

(a)   This was a straightforward introductory part of the question that was well answered by the majority of the candidates. A small number of candidates incorrectly gave the final answer as $N\,m^{-2}$ and not in terms of SI base units.

(b) (i)   The calculation was straightforward for the more able candidates who presented all their work clearly. Weaker candidates tended to miss out steps in the presentation of their calculation, which makes it difficult for them to avoid errors or check their work.

There were three common types of error. One was to forget to cube either the value of the length of the beam or the value of the thickness of the beam. Another was power-of-ten errors caused by wrongly interpreting the prefixes of the units given in the question. Finally some candidates made arithmetic errors in wrongly rearranging the equation.

   (ii) 1. More candidates understood what is meant by accuracy than what is meant by precision. A significant number of candidates confused precision with accuracy. Some candidates referred to significant figures, scale divisions, systematic errors and random errors, but did not actually answer the question that had been set.

2. Most answers stated that the length of the beam contributed more to the uncertainty in the value of the Young modulus, but very few were able to explain why. Sometimes it was explained that the percentage uncertainty of the length would be multiplied by three, but without comparing it with the time period (whose percentage uncertainty would be multiplied by two). Weaker candidates sometimes contradicted the question by trying to explain why the length and time period measurements would have different percentage uncertainties.

Question 2

(a) Straightforward recall of knowledge was needed to answer this part of the question. Weaker candidates sometimes said that 'the forces are zero' rather than 'the resultant force is zero'. Another common error was to say that 'the moments are zero' rather than 'the resultant moment is zero'. A small number of candidates referred to momentum instead of moment.

(b)(i) Most answers were fully correct. A very small number of candidates thought that acceleration was equal to velocity divided by time rather than the change in velocity divided by the corresponding time interval.

(ii) The great majority of candidates understood that the simplest way of calculating the distance was to find the appropriate area under the graph. However, some candidates wrongly calculated the entire area under the given graph rather than the area from $t = 0$ to $t = 7.0$ s. A significant number of candidates calculated the area under the line from $t = 4.0$ s to $t = 7.0$ s using the formula for the area of a triangle instead of the area of a trapezium.

An alternative method of calculation was to apply the equations of motion, although the candidates who adopted this method tended to be less successful.

(iii) The majority of answers were correct. A common error was to use a final speed of $10\,\text{m s}^{-1}$. As part of their calculation, a small number of candidates squared the difference in the two speeds, instead of finding the difference in the squares of the two speeds.

(iv) 1. Most candidates could calculate the vertical component of the tension in the wire. Only the stronger candidates realised that they also needed to take into consideration the weight of the paraglider in order to determine the vertical lift force.

2. Many candidates were able to calculate either the horizontal component of the tension in the wire or the resultant horizontal force on the paraglider. Stronger candidates could combine these two forces to determine the air resistance acting on the paraglider in the horizontal direction.

Question 3

(a) There were many good answers where candidates were able to convert the unit prefixes given in the question into the correct power-of-ten values. The clear and explicit presentation of all the steps in the calculation was essential in this 'show that' question. If candidates chose to calculate the values of the mass and the volume, it was important that these values were not prematurely rounded. Candidates needed to wait until the final answer before rounding to two significant figures. A significant minority of candidates inappropriately used the symbol d instead of ρ to represent the density of the material, and this could be confused with diameter.

(b)(i) A precise explanation was needed. The centre of gravity is the point where all the weight of a body seems to act. Common mistakes included not referring to a 'point', referring to mass instead of weight and omitting 'seems to' or equivalent wording.

(ii) This was a straightforward calculation for most candidates, although sometimes an incorrect distance was used when calculating the anticlockwise moments.

(c)(i) A small number of candidates described the upthrust as being due to the density of the material of the cylinder being less than the density of the water. This may be true but the origin of the upthrust must involve pressures or forces. Others simply quoted Archimedes' principle which did not answer the question. A common misconception was that Newton's third law meant that the weight of the cylinder caused an equal and opposite force which was the upthrust.

(ii) Most candidates recognised that the system would no longer be in equilibrium due to the upthrust, but very few could give a complete explanation, in terms of moments, of why the weight of X must be reduced. The majority of explanations wrongly focused only on the changes to the forces without considering what was happening to the clockwise and to the anticlockwise moments.

Question 4

(a) Although this part of the question tested simple recall of knowledge, there were many incomplete answers. Most candidates realised that two waves of the same frequency were needed. However, many candidates did not say that the two waves must be travelling in opposite directions or that the waves must overlap.

(b) (i) The correct wavelength was usually calculated, although weaker candidates were often unable to use the value of the wavelength to calculate the distance between the ends of the string.

(ii) Only the more able candidates could give appropriate answers to this part of the question. Weaker candidates often assumed the wave to be progressive, rather than stationary, and so drew their new waveforms shifted to the right of the given waveform. Some candidates did not read the instruction that they should draw their sketch on Fig. 4.2 and instead drew their sketch on a blank area of the page. Those candidates were often unsuccessful because it was not possible to compare their sketches to the given waveform.

Question 5

(a) Candidates needed to give a carefully worded description of the Doppler effect. It was insufficient just to refer to 'a change in frequency' instead of saying that the observed frequency is different to the source frequency. It was also insufficient just to say that 'the source moves' instead of saying that the source moves relative to the observer.

(b) Most candidates were able to copy down the correct formula from the formulae page. Some candidates did not understand what the symbols represented and substituted in the wrong numerical values. A small number of candidates wrongly used an expression for a moving observer instead of the expression for a stationary observer. This was unexpected because the syllabus limits treatment of the Doppler effect to the situation of a source moving relative to a stationary observer.

Question 6

(a) Units are only defined in terms of other units and not in terms of quantities. A common incorrect definition was 'voltage per unit ampere' which confuses volt and voltage. The weakest candidates sometimes gave the definition for resistance or just stated Ohm's law.

(b) (i) The great majority of answers were very good. There were a number of different methods of calculating the current in the circuit. The most common was first to calculate the total circuit resistance and then to use this with the terminal potential difference of the cell. A small minority of candidates made an arithmetic error when calculating the combined resistance of the two resistors in parallel.

(ii) This question proved to be more difficult. Different methods of calculating the answer were possible. A common error was to assume that the current in resistor B would be one third of the total current in the circuit, not realising that the current in resistor B would be twice the current in resistor A.

(iii) Most candidates used a correct power formula. Candidates who used $P = I^2R$ were usually able to calculate the correct answer. Those who used $P = IV$ or $P = V^2/R$ sometimes substituted in an incorrect value of potential difference.

(c) (i) Most candidates correctly explained that the wires should have different cross-sectional areas. A significant number of candidates wrongly suggested varying the type of material or the length of the wires, even though the question explicitly stated that these were the same. It is important that candidates read the question carefully to avoid this type of mistake.

(ii)   The calculation of the ratio of average drift speeds was found to be difficult by the majority of candidates. Most candidates realised that there were different currents in the two resistors, but wrongly assumed that the cross-sectional areas were the same.

(d)   Candidates found this question very difficult and many candidates would benefit from improving their understanding of how circuits operate when they incorporate cells that are connected in parallel. It is recommended that candidates practise answering questions involving cells connected in parallel when they are being taught this part of the syllabus.

Question 7

(a)   Most candidates could derive the charge of a proton and of a neutron from the charges of their constituent quarks. Weaker candidates could state the correct names of the constituent quarks, but did not know the values of the charges carried by those quarks.

(b)(i)   A small number of candidates understood how a nucleus changes when it emits a β^- particle and when it emits a β^+ particle. A common misconception is that beta decay changes the nucleon number of the parent nucleus.

(ii)   This part of the question required straightforward recall of knowledge. The most common incorrect answer was 'strong force'. Many candidates either stated just 'nuclear force' or left the answer line blank.

(iii)   Most candidates could name only one of the two leptons produced in each decay process.

PHYSICS

Key messages

- Candidates should carefully use the appropriate physics terms when producing definitions, written explanations or descriptions. A missing key word or an incorrect word may prevent the candidate from being awarded credit.

- In 'show that' questions, candidates should methodically write down each step in their calculation leading to the final answer. Well-presented calculations enable candidates to check that the solution is correct and clearly demonstrate that the answer they obtain is the value given in the question.

- In numerical solutions, candidates sometimes show their working with an expression that does not have a subject. There are times when the subject changes because of changes made to the expression. If the final answer is incorrect then credit for this type of working often cannot be awarded. Candidates should be encouraged always to provide a subject of any equation. Rearrangement of equations is only possible with the inclusion of the subject.

General comments

The rounding of figures at intermediate stages in numerical questions can produce inaccurate answers and should be discouraged. Very few candidates provided answers with too few significant figures or used the approximation $g = 10\,\mathrm{m\,s^{-2}}$ inappropriately.

Candidates should be encouraged to read the question carefully to ensure their answers are appropriate in context, rather than simply attempting to recall memorised extracts.

In **Question 6**, many candidates found it difficult to apply their understanding of wave theory to the interference of water waves. In **Question 7**, many candidates were not able to explain the potential difference changes across the various components in a series circuit when the resistance of the circuit was altered.

There was no evidence that candidates were short of time to finish their answers.

Comments on specific questions

Question 1

(a)   The majority of candidates were able to name two other base units. Occasional incorrect answers were joule, volt, ohm and coulomb. Very few candidates confused base units with base quantities.

(b)   A large number of candidates made a good attempt. The majority started well by quoting the correct formulas for resistivity and either $R = V/I$ or $R = P/I^2$. Most of the successful candidates determined the base units from the definition of potential difference rather than power. There were a significant number who made a slip with incorrect cancelling or analysis of the powers for the base units. Practice with these more complicated powers for base units would give confidence to candidates and enable them to reach the correct answer.

A small minority of candidates just stated $\Omega\,\mathrm{m}$, or sometimes $\mathrm{V\,A^{-1}\,m}$. A number of candidates calculated the base unit for resistance instead of resistivity. A small minority used the coulomb as a base unit.

(c) (i)   The majority of candidates made a good attempt. The expression for resistivity was known by most candidates. A significant number of candidates were unable to convert the area into m^2 or the value for the resistivity into $n\Omega\,m$.

(ii) 1.   Many candidates referred to values or measurements being close to the true value instead of being close to each other. There was a general confusion between accuracy and precision.

2.   The majority of answers were not specific to the measuring devices quoted in the question. Very few were able to give numerical values.

Question 2

(a)   Most candidates gave the correct definition. There were a minority of unacceptable answers such as 'speed in a certain direction', 'rate of change of displacement per unit time', 'displacement over time' or using distance instead of displacement. A few candidates gave 'displacement per second' which cannot be given credit as it is a mixture of quantities and units.

(b) (i)   The more able candidates generally separated the vertical and horizontal components and worked through to a correct solution. Many candidates confused the two distinct components of the motion, calculated the vertical velocity of the ball and placed this as the answer to the horizontal velocity. Others used the horizontal displacement with the vertical acceleration in the same equation, revealing a deep-seated misunderstanding of the idea of separating the horizontal and vertical components when dealing with projectiles.

(ii)   The more able candidates calculated the vertical velocity and then used the horizontal velocity to determine the resultant velocity. Many weaker candidates calculated the vertical velocity of the ball and placed this as the answer for the resultant velocity. Some used Pythagoras' theorem with the vertical and horizontal distances to find a distance travelled of 1.95 m, and incorrectly used that in a vertical equation of motion to arrive at the answer.

Candidates would gain from practising this kind of problem, which goes further than just a simple, straightforward application of a single equation of uniform acceleration. The calculation of the angle was generally done better. There were a significant number of responses that used trigonometry with the ratio of the vertical and horizontal displacements rather than the velocities.

(iii)   Most candidates obtained a correct answer. A small minority obtained only partial credit as they did not square the velocity.

(iv)   The majority of candidates calculated the correct answer. A small minority subtracted their correct answer from the kinetic energy calculated in **(b)(iii)**. This gives the initial kinetic energy.

(c)   Many candidates ignored the information that air resistance is negligible, and attributed the difference to a loss of energy to the surroundings in the form of heat.

Question 3

(a)   A large number of candidates gave the correct starting equation for the Young modulus. Common mistakes in the calculation were a power of ten error in the calculation of the gradient or in the radius, using just a single point solution (which is not valid because X is not the extension) and not converting the diameter into a radius. The conversion to TPa was generally done correctly by stronger candidates.

(b)   The majority of answers stated that the force must be larger, but the question asked about the *range*, so candidates needed to clearer that they would use a larger range of forces when the experiment is repeated.

Question 4

(a) Many candidates found it difficult to provide an acceptable definition owing to the omission of keywords or the use of inappropriate words. Some candidates used phrases such as 'uniform motion' or 'constant speed' without the qualification that this must be in a straight line or must be constant velocity. It was uncommon for candidates to refer to a resultant force.

(b) (i) The majority of candidates obtained credit for showing that the collision involved four distinct momentum terms. Less able candidates often obtained an incorrect answer by ignoring the signs of the velocities for the two objects both before and after the collision.

(ii) A significant number of candidates were able to state that the kinetic energy was not conserved but that the kinetic energy was changed to other forms of energy. A number of candidates stated that the momentum was conserved and kinetic energy was not conserved but without any discussion of what happened to the 'missing' kinetic energy or any mention of total energy. Some weaker candidates omitted the term 'kinetic' and just said that energy would be lost as heat/sound etc., and some gave answers in terms of relative velocities which were not related to energy.

Question 5

(a) Candidates were often not awarded credit because they omitted key words, or gave definitions that were a mixture of quantities and units (e.g. 'number of oscillations per second'). Many candidates stated 'number of waves per unit time' or quoted the wave equation.

(b) The majority of candidates suggested that the particles moved 'with the sound wave' and did not state that they vibrated parallel to the direction of travel of the sound wave about a fixed position. A minority of weaker candidates described a transverse wave by saying that the motion was perpendicular to the direction of travel of the wave.

(c) (i) The majority of candidates were able to determine the correct time period from the c.r.o. trace and then the frequency. A common error was to ignore the time period units of ms.

(ii) A significant number of candidates recognised the Doppler effect in this question and gained credit for changes in wavelength or time period. Only the strongest candidates realised that there would also be a change in amplitude as a result of the change in distance between the car and microphone.

Question 6

(a) (i) Diffraction is a wave phenomenon and the descriptions of diffraction needed to be in terms of what happens to the waves as they pass through the slits. Many candidates did not consider waves spreading through the slits and then overlapping. It was common for candidates to use the term 'light' rather than identifying a wave.

(ii) The majority of candidates correctly understood that two separate sources of light would not produce coherent waves, or waves with a constant phase difference, and that the need for these conditions was the reason for the double slit.

(b) A significant majority of candidates were able to determine the wavelength. Most stated the correct equation for a double slit. Some candidates made a mistake in determining the fringe width, with omission of the required division by 16 or obtaining twice the correct answer.

(c) (i) Candidates need to take care to read this type of question carefully. The question asked for what is *observed* at point P, but many candidates made no mention of water in their answers. The majority of candidates started their answer by stating that constructive interference took place, mainly due to reading that the phase difference of the waves at D_1 and D_2 was zero and taking this to mean that the phase difference at P was zero. Candidates often stated that the water level had risen or a maximum was seen rather than that the water was vibrating.

Those candidates who realised that it was destructive interference often stated that a 'dark fringe' would be seen at P. Some stated that there are no waves or a minimum rather than the water being still/stationary. Some calculated a value of 2.5λ but gave no link with the path difference.

(ii) Candidates found this question difficult. Few candidates described the effect on the water surface at P, and candidates found it difficult to relate the two changes in the conditions to their knowledge of interference of waves. In **part 1** many candidates started their answer by stating that destructive interference took place (mainly due to reading that the phase difference of the waves at D_1 and D_2 was 180°). As in **(i)**, a 'dark fringe' being seen at P was a common answer. In **part 2** many candidates demonstrated the misconception that interference could not take place as the amplitudes were different.

Question 7

(a) The majority of candidates gave a description of energy changes, but not specifically those that are relevant to the particular case of the e.m.f. of a cell. Many candidates omitted to say 'per unit charge'. Some mentioned charge but did not correctly indicate that the energy is divided by charge.

(b)(i) The more able candidates realised that increasing the resistance causes the current to decrease, and then considered the changes in potential difference across the various components in the circuit. Many candidates gave answers without reference to the internal resistance. Some weaker candidates thought that increasing the p.d. across Y would reduce the p.d. across AB. Others stated that the p.d. across AB would increase because R is increasing in $V = IR$, and treated I as being constant. Another common error was to say correctly that increasing the resistance would reduce the current, but then incorrectly reasoning that reduced current suggests a smaller p.d. across the cell. Only a minority of candidates appreciated the essential role of the p.d. across the cell's internal resistance in constructing a sensible argument.

(ii) 1. The majority of candidates obtained the correct answer. A small minority did not include the internal resistance in their calculation. Some calculated the total resistance of the circuit (using $R = 1.50 / 0.180 = 8.33 \, \Omega$) but then, instead of subtracting 6.20 from it, presented this on the answer line as the resistance of X.

2. A significant number of candidates obtained the correct answer. Some candidates calculated the 'lost volts' and gave this as the answer for the terminal p.d. Some candidates were not aware that the p.d. across XY was the same as the p.d. across AB. A number of weaker candidates obtained a terminal p.d. that was greater than the e.m.f. but did not realise that this could not be correct in this circuit.

3. A large number of candidates gained full credit. Candidates should be encouraged to write a starting point such as 'efficiency = power output / power input' rather than just 'output / input' or a series of numerical values, because partial credit may then be given if the numerical answer is not correct. A very small number of candidates forgot to include the % sign when they converted to a percentage.

Question 8

(a) A large number of candidates produced clear, well-organised answers on beta decay. The most common answer referred to the emission of an antineutrino or neutrino. A minority correctly answered in terms of quarks and/or gave the correct change in proton number.

A significant number of candidates mixed up β^- and β^+ in one or both parts, or gave only partial responses such as the decay of a neutron or proton instead of describing what they changed to. In some cases, candidates gave effectively only one response, such as 'β^- emission produces an antineutrino' and 'β^+ produces a neutrino' (which is only one difference). Weaker candidates often did not discuss the decay but described the differences between a β^- particle and a β^+ particle.

(b) The majority of candidates were able to state the correct composition of two of the three quarks for the proton (up, up, down) and the neutron (up, down, down). The question directed candidates towards a three-quark model but a very small number of candidates explicitly stated that the proton and neutron do not contain the strange quark.

PHYSICS

> **Paper 9702/23**
> **AS Level Structured Questions**

Key messages

- Candidates should carefully use the appropriate physics terms when producing definitions, written explanations or descriptions. A missing key word or an incorrect word may prevent the candidate from being awarded credit.

- In 'show that' questions, candidates should methodically write down each step in their calculation leading to the final answer. Well-presented calculations enable candidates to check that the solution is correct and clearly demonstrate that the answer they obtain is the value given in the question.

- In numerical solutions, candidates sometimes show their working with an expression that does not have a subject. There are times when the subject changes because of changes made to the expression. If the final answer is incorrect then credit for this type of working often cannot be awarded. Candidates should be encouraged always to provide a subject of any equation. Rearrangement of equations is only possible with the inclusion of the subject.

General comments

The rounding of figures at intermediate stages in numerical questions can produce inaccurate answers and should be discouraged. Very few candidates provided answers with too few significant figures or used the approximation $g = 10 \, \text{m} \, \text{s}^{-2}$ inappropriately.

Candidates should be encouraged to read the question carefully to ensure their answers are appropriate in context, rather than simply attempting to recall memorised extracts.

In **Question 5**, many candidates found it difficult to apply their understanding of wave theory to the interference of waves leaving a diffraction grating. In **Question 6** many candidates were not able to explain the potential difference across the various components in a series circuit.

There was no evidence that candidates were short of time to finish their answers.

Comments on specific questions

Question 1

(a) (i) The majority of candidates gave the correct answer.

(ii) The majority of candidates gave the correct answer.

(b) (i) A significant number of candidates gave a correct solution for this 'show that' question. Those candidates who resolved forces generally gave clear, easy to follow solutions. The scale drawing method was often poorly presented. The diagram was often too small with no mention of the scale used or arrows to indicate the directions of the forces. The length of the resultant was often not the required value for a resultant force of 65 N even within the tolerance allowed. Some candidates used the cosine rule but this was not the method required by the question.

(ii) The candidates using resolution of forces generally were able to use the correct trigonometric relationship to determine the angle. The angle was also generally within tolerance from the scale diagrams. A significant number of weaker candidates were unable to construct a vector diagram of the forces or resolve the forces correctly.

(c) Many candidates obtained the correct answer. There was some misinterpretation of the question or misreading of the introduction. This meant that some candidates took the resultant force to be 80 N or some added the 80 N to the 65 N. Most candidates correctly used the equation $F = ma$.

Question 2

(a) Some candidates missed key words such as the 'rate of change' of momentum or the change in momentum 'per unit time'. A significant number gave $F = ma$ but this is not a statement of the second law.

(b)(i) Most candidates were able to determine the change in momentum. There were very few misreadings of the graph and the mass was correctly converted to kilograms by most candidates.

(ii) The majority of candidates obtained a correct answer. The force was determined either using $F = \Delta p / \Delta t$ or $F = ma$ with acceleration determined from the gradient of the graph.

(c)(i) Many candidates misread the question and calculated the combined momentum of A and B before and after the collision. A small minority correctly showed that the change in momentum of A was equal and opposite to the change in momentum of B.

(ii) The more able candidates were able to explain how the answers to **(c)(i)** supported Newton's third law. Many candidates were not able to combine the time of the collision for A and B being the same and the change in momentum of A and B being equal and opposite to reach a conclusion, i.e. that the force acting on A from B is equal and opposite to the force acting on B from A.

(iii) The majority of candidates were not able to use the relative speed of approach compared with the relative speed of separation to show the collision was inelastic. Some candidates used the given speeds to show the kinetic energy was less after the collision than before. A common error was to give an explanation that did not involve reference to speeds.

Question 3

(a) Most candidates gave the correct definition. A significant number of candidates gave the expression for a uniform field produced by a p.d. applied between two plates, or did not make clear the ratio of force and charge in the definition.

(b)(i) Most candidates started with the correct equation and many went on to calculate the acceleration correctly. A significant number made errors due to powers of ten in the distance AB or the initial and final velocities.

(ii) A significant number of candidates were able to get to a correct value for the change in kinetic energy.

(iii) Many candidates were able to determine the force acting on the electron. Some arithmetic errors were made rearranging the equations linking force and electric field strength. There were many who were unable to link the force, acceleration and electric field strength with suitable equations. Some candidates successfully linked the change in kinetic energy to the work done on the charge by the field.

(c) Candidates found this question difficult. A significant number were able to state that the charge on the electron was opposite to the charge on the α-particle, but could not give a clear explanation of the effect on the change in kinetic energy. A significant number thought that the difference in mass made a contribution to the difference in kinetic energy. Very few candidates realised that the kinetic energy would be reduced for the α-particle.

Question 4

(a)   Many candidates did not give enough detail. The spring does not obey Hooke's law as the relationship is not a straight line through the origin.

(b)   Most candidates gave the correct answer. A significant number of candidates stated only 'potential energy' and this was not detailed enough to be awarded credit.

(c)   A large number of candidates were able to give a clear description of how to determine whether the extension is elastic. Some candidates suggested looking for the point where the extension is no longer proportional to the load. This confuses the limit of proportionality with the elastic limit.

(d)   There were very few correct answers because the area under the line was often not determined correctly. Many candidates used the maximum force rather than an average force. The conversion of the mass to a force and conversion of the extension from mm to m led to many errors in this calculation. It would be worthwhile for candidates to practise calculating the area of a trapezium or dividing the area into two parts, a rectangle and a triangle.

Question 5

(a) (i)   A small number of candidates were able to describe diffraction. Diffraction is a phenomenon associated with waves so candidates needed to mention waves (rather than just 'light' etc.) in a complete answer.

(ii)   The more able candidates were able to explain the overlapping of waves to give the various orders. The path difference for these waves to give the zero and first order maxima was described by stronger candidates. It was common for candidates not to say explicitly that the waves meet.

(b) (i)   Most candidates were able to determine the gradient. A small minority made errors reading the points on the graph.

(ii)   The majority of candidates quoted the correct expression. Common errors were in the powers of ten in the wavelength, the order of the maximum and linking the gradient correctly with the equation.

(iii)   There were very few candidates who were able to interpret from the diffraction grating equation that the angles for the first order would be less and gradient would also be less. In general, weaker candidates tended not to answer this question.

Question 6

(a) (i)   A significant number of candidates could describe the correct relationship between I and V for a metallic conductor.

(ii)   Candidates found it difficult to describe the main features of the $I–V$ characteristic for a semiconductor diode. Some candidates might have benefited from first trying to sketch a graph of the relationship.

(b) (i)   A large number of candidates incorrectly considered the p.d. across each lamp to be 12 V in the series circuit. These candidates generally obtained the correct current for the lamp when in parallel but many only considered the current for one lamp and not for the battery.

(ii)   Candidates generally were able to calculate the total resistances of the circuits.

(iii)   The majority of candidates gained credit for a correct expression for electrical power. Those candidates who used I^2R tended to be more successful than those using IV. Candidates using IV often tended to use an incorrect p.d. across the lamp when in series.

Question 7

(a)   A small number of candidates correctly gave both the quark and the electron.

(b) (i)   A significant number of candidates were able to determine the two values required. Weaker candidates generally did not know how to proceed and could not attempt to answer the question.

(ii)   This was correctly stated by about half the candidates. Many weaker candidates seemed to guess the particle rather than deducing it from the equation, and these candidates might benefit from further study and/or practice on this area of the syllabus.

PHYSICS

Paper 9702/31
Advanced Practical Skills 1

Key messages

- Many candidates find it difficult to choose scales that make good use of the graph grid. The aim should be to occupy the majority of the graph grid. If less than half of the grid is occupied in one direction, the range of the corresponding axis can be halved to make better use of the grid.

- It is important that candidates always show clearly how a numerical value has been obtained. For example, in **Question 1**, where the gradient of a straight line is calculated, it is a good idea to mark both read-offs on the graph and draw lines to construct a right-angled triangle. All the steps in calculating the value of the gradient, including the read-offs themselves, should be shown. It is also helpful to determine the units of the gradient at this stage, as this will be useful for the last part of the question.

- In order to calculate the percentage (or fractional) uncertainty in a measurement, some judgement has to be made about the absolute uncertainty of the measurement. Candidates often just use the precision of an instrument being used. Estimating the absolute uncertainty should also take into account the effect of extraneous influences (e.g. draughts and changes in temperature), uncertainties in judgement (e.g. when judging the start or finish of an oscillation) and even uncertainties caused by the act of measurement itself (e.g. putting a cold thermometer into a beaker of hot liquid will cool the liquid very slightly).

- 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.

Successful candidates showed confidence in connecting the circuit correctly and were at ease with reading the meter correctly. This confidence will have been gained from time spent using electrical apparatus frequently.

Candidates appeared to have sufficient time and both questions were attempted by almost all the candidates. They demonstrated good skills in the generation and handling of data.

CAMBRIDGE
International Examinations

Comments on specific questions

Question 1

(b)(iii) Successful candidates read the instruction that distance x should be approximately 40 cm. They then positioned the crocodile clips correctly and recorded a current in the appropriate range. Some candidates were confused with the scale, noting a current reading of, for example, 120.1 A rather than 120.1 mA. Some weaker candidates did not write a unit for their current.

(c)(iii) Successful candidates placed the additional lead L in the correct place such that $I_2 > I_1$. Some candidates placed the lead in the wrong place, leading to a reduction in the current.

(d) Successful candidates collected six sets of values for x, I_1 and I_2 showing that as x increased both I_1 and I_2 decreased.

Stronger candidates noticed the instruction to increase x, and made full use of the apparatus. Others used values of x less than 40 cm, and this often led to a reduced range.

The strongest candidates drew neat, well-constructed tables. Candidates should be encouraged to include a separating mark, such as a solidus, between the quantity and unit e.g. I_2 / mA. The majority of candidates gave x / cm and I_1 / mA and no unit for (I_2 / I_1), but some omitted the unit for current or wrote (I_2 / I_1) / mA / mA and could not be awarded credit.

The metre rule provided had mm markings. Successful candidates were consistent with precision and used mm when recording all their values of x. Some candidates used this level of precision for most readings but not all, e.g. 40.0, 90.0 and 100. Candidates should keep the number of decimal places, not the number of significant figures, consistent.

Many candidates recorded their calculated values for (I_2 / I_1) to an appropriate number of significant figures from their raw data, i.e. the same number of significant figures (or one more significant figure) than their raw current values.

Most candidates were able to calculate (I_2 / I_1) correctly. Many of the errors in the calculations were due to incorrect rounding or truncation of the final value.

(e)(i) There are two particularly important elements in producing a successful graph. Firstly, candidates should plan scales to produce points which spread over the majority of the grid. Secondly, the scale should be chosen so that it is easy to interpret the position of points without using a calculator. Many candidates were unsuccessful because the plotted points only occupied two or three large squares in the y (I_2 / I_1) direction. Some candidates omitted the axis labels or wrote only units for the labels.

A fine pencil with a sharp point is an essential tool. Successful candidates had access to sharp pencils to draw accurately placed points, and they drew points with a diameter smaller than half a small square.

(ii) Successful candidates were able to draw a good line of best fit through their six points, with points well balanced along the whole length of the line.

Candidates could also gain credit if they drew a line through five trend points but identified <u>one</u> 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. Before marking a point as anomalous, candidates should check that the point is plotted correctly and that the scale increases regularly with no missing values, and they should ideally check the measurement to be sure that readings were taken and recorded correctly. Only one point, if any, should be identified as anomalous.

When a line is drawn, successful candidates looked at the balance of points around their whole line. Those candidates who chose to join the first and last points or joined up a couple of points often produced a line which was unbalanced and needed to be rotated or shifted.

(e) (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 needed also to check that the triangle for calculating the gradient was large enough (the hypotenuse should be greater than half the length of the line drawn). If the gradient is negative (which could be the case if the readings had the wrong trend), candidates should include the negative sign in the gradient answer.

Some candidates were able to read off the *y*-intercept correctly at *x* = 0 directly from the graph. Many candidates incorrectly read off the *y*-intercept when there was a false origin.

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

Candidates should take care to use $c = y - mx$ and not the incorrect equation $c = y / mx$.

(f) Most candidates recognised that *P* was equal to the value of the gradient and *Q* was equal to the value of the intercept calculated in **(e)(iii)**. Stronger candidates made a direct transfer of the values in **(e)(iii)** to **(f)**. No calculation was needed.

Correct units were given by successful candidates, but other answers omitted units. It was common for candidates to write a unit with the gradient and intercept in **(e)(iii)** but then not transfer these units to **(f)**.

Question 2

(b) (ii) The time for each string should have been close to 5 s. Some candidates recorded times as 0.05 s indicating that the stopwatch had been misread. Other candidates recorded time as a whole number of seconds rather than recognising the precision of the stopwatch.

(c) (ii) The shapes of the ball and the wooden block meant that there was a challenge in aligning the rule and eyes to measure *x*. Successful candidates recorded a value to the nearest mm, gave the correct unit and had a value in the right range. Successful candidates had taken care that the original length was 35 cm so their measurement of *x* was in range.

(iii) Most candidates were familiar with the equation for calculating percentage uncertainty and many made a realistic estimate of the absolute uncertainty in *x* i.e. 2–5 mm. Successful candidates realised that the absolute uncertainty in the value of *x* depends on more than just the precision of the measuring instrument. They also realised that it was difficult for this measurement to be accurate because of the shapes involved.

When repeat readings were noted, the absolute uncertainty could be calculated as half the range of the repeated values. Some candidates used the full range and this was not awarded credit. The half-range calculation needed to be shown so that it was clear how the estimate of absolute uncertainty had been produced.

(e) (i) Successful candidates spent time repeating the experiment to gain an understanding of how to count the oscillations, and recorded several values of *n* in the range 10–20. It was evident from answers that some candidates were counting half an oscillation as a full oscillation. Weaker candidates often recorded only one value of *n*.

(ii) Most candidates correctly calculated a value for $(n + 1)^2 / n^2$ and gave their answer correctly rounded. Some candidates truncated their answer rather than rounding it correctly.

(f) Most candidates successfully recorded second values for *x* and *n*, and found that the value of *n* decreased when the longer wooden block was used.

(g) (i) Many candidates successfully rearranged the equation and calculated $k = [(n + 1)^2 / n^2] / x$ for both experiments. Some candidates misunderstood how to rearrange the equation and incorrectly used $k = [x / (n + 1)^2] / n^2$. The aim here is to record two values of k and analyse whether they indicate support for the relationship. Some candidates 'make' the two values of k equal by rounding to one significant figure.

Some candidates retake measurements when they find the k values are different. This is unnecessary. If it is done, the new values need to be used and taken through into the calculation of k so that all the data used are consistent.

(ii) Successful candidates had three steps in their argument. They first state a criterion to be used for testing the relationship. This could be a percentage uncertainty that they think is a sensible limit for this particular experiment, e.g. 5% or 20%, or could be the percentage uncertainty found in **(c)(iii)**. Next they calculate the percentage difference between their values of k. Finally, they compare the percentage difference between their k values to the percentage uncertainty chosen and decide whether the relationship is supported or not supported. If the percentage difference between the two k values is less than the stated criterion, these successful answers then say that the relationship is supported. If the value of the percentage difference is greater than the value of the percentage uncertainty stated as the criterion, then the relationship is not supported. The candidates should make an explicit statement, e.g. 'the relationship is not supported'.

Some candidates did not give any criterion to test against. Many statements were too vague. Some candidates looked at the difference without determining a percentage. These did not gain credit.

(h) Successful candidates correctly calculated L using $1 / k$ and gave their answer to three significant figures. Some candidates did not give three significant figures.

(i) **Question 2** is designed to have limitations or uncertainties in the way that the readings are taken. Successful candidates thought about problems while doing their experiments, wrote these down, and then made valid suggestions for an improved method. These candidates communicate their thinking about why it is difficult to make a measurement.

A key problem in this experiment is that using only two wooden blocks of different length is not sufficient to find a relationship or see a pattern in the results. Successful candidates stated that 'two sets of readings were not enough to draw a conclusion'. Simply stating 'two readings are not enough' did not gain credit.

The key to success in this section is for candidates to identify genuine problems associated with taking accurate readings during the experiment. The main areas that could be considered here were difficulty with seeing when the balls were in phase, difficulty measuring x with the reason why it was difficult, and problems with the balls hitting each other.

Identifying when the balls were back in phase was a challenge and having to count until they were back in phase was correctly identified as a difficulty by many candidates. A video camera was a possible improvement but candidates needed to give some detail to suggest where it would be placed.

Some candidates identified that it was difficult to measure length x due to the shape of the balls and the wood and trying to arrange the rule close to the length to be measured. This linked to finding the percentage uncertainty in x which candidates had thought about earlier. A statement 'difficult to measure the length' on its own did not gain credit.

Successful answers suggest detailed limitations and improvements specific to this oscillation experiment. Statements of general 'errors', 'systematic errors', 'zero errors', etc. cannot be awarded credit when they are not specific to the experiment. Credit also is not given for suggestions that should already have been done as part of the experiment, such as repeating measurements and calculating averages. General statements of improvement such as 'use an assistant' or ''view at eye level' also do not gain credit.

PHYSICS

Paper 9702/32
Advanced Practical Skills 2

Key messages

Many candidates find it difficult to choose scales that make good use of the graph grid. The aim should be to occupy the majority of the graph grid. If less than half of the grid is occupied in one direction, the range of the corresponding axis can be halved to make better use of the grid.

It is important that candidates always show clearly how a numerical value has been obtained. For example, in **Question 1**, where the gradient of a straight line is calculated, it is a good idea to mark both read-offs on the graph and draw lines to construct a right-angled triangle. All the steps in calculating the value of the gradient, including the read-offs themselves, should be shown. It is also helpful to determine the units of the gradient at this stage, as this will be useful for the last part of the question.

In order to calculate the percentage (or fractional) uncertainty in a measurement, some judgement has to be made about the absolute uncertainty of the measurement. Candidates often just use the precision of an instrument being used. Estimating the absolute uncertainty should also take into account the effect of extraneous influences (e.g. draughts and changes in temperature), uncertainties in judgement (e.g. when judging the start or finish of an oscillation) and even uncertainties caused by the act of measurement itself (e.g. putting a cold thermometer into a beaker of hot liquid will cool the liquid very slightly).

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. The work of some candidates was difficult to mark because the handwriting was not clear, particularly for numerical data. Candidates should be encouraged to write carefully, as credit can be awarded only when it is possible for examiners to see what the candidate has written.

Comments on specific questions

Question 1

(a) (v)   Most candidates recorded a value for p in the expected range, although in a few cases the unit was missing. In the small number of cases where the value of q was greater than p, it is probable that it was being measured from the end of the wooden strip rather than from the screw.

(b)   Most candidates recorded six sets of values of p and q without any assistance from the Supervisor. In a few cases, full credit could not be given because values of V were not included in the table, or because each increase in p did not produce an increase in q.

Â A small number of candidates included a sufficiently wide range of p values in their table, but in many other cases the data did not include values from the lower end of the available range.

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

All measurements of p and q should have been recorded to the nearest mm. The values for p were selected by the candidate and so could have been chosen all to be whole cm, but they should still have been recorded to the nearest mm (e.g. 25.0 cm or 0.250 m).

For this experiment, giving the calculated values of $1/q$ to the correct number of significant figures often meant that the number of decimal places varied down the column in the table. Many candidates were uncomfortable with this and rounded their values too much to obtain the same number of decimal places.

The calculations themselves were nearly always correct.

(c) (i)   Most graphs were drawn to a good standard, with accurate and clear plotting of points.

Scales were usually simple, so it was easy to avoid mistakes when reading off coordinates. In some cases the points were compressed into too small an area of the grid, or were drawn using dots that were too large. 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.

The quality of the candidates' work 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.

(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 as the $1/p$ axis did not start at zero.

(d)   Most candidates recognised that a was equal to the value of the gradient and b was equal to the intercept (as calculated in **(c)(iii)**).

Most candidates included a correct unit for their b value, but a few either omitted this unit or mistakenly added a unit to their value for a.

Question 2

(a) (ii)   Nearly all candidates recorded a value for h_1 to the nearest mm. In a few cases, a value in cm was recorded without amending the unit of m already on the answer line.

(iii)   After adding more mass, the value of h_2 was expected to be smaller than h_1. This was found to be the case by nearly all candidates.

(iv)   The added 100 g mass had a larger diameter than the mass hanger itself so the rule could not be positioned next to the mass hanger when measuring its height above the bench. This led to

difficulty with parallax and so the uncertainty of 1 mm chosen by many candidates was unrealistically small. A number of candidates had difficulty converting the unit for their suggested uncertainty to m (e.g. 2 mm was changed to 0.02 m).

(b) (i) Most candidates calculated k accurately.

(ii) When discussing the number of significant figures given for k, there were many cases where the candidate's statement was correct but lacked detail. Candidates could be awarded credit for a detailed answer such as '3 sig. figs. were used because m, g and $h_1 - h_2$ all had 3 sig. figs.' A more vague statement such as 'all data used to calculate k had 3 sig. figs.' was not accepted.

(c) (iii) The majority of candidates were given credit for timing a sequence of oscillations (e.g. 5T) as part of their technique. The value of T should have been about 1.5 s, but many candidates recorded values of about 0.75 s, suggesting that ½T was measured.

(d) The measurements using three springs were awarded credit for nearly all candidates. Most candidates correctly found that T increased.

(e) (i) Most candidates were able to calculate C correctly for each of the two sets of springs, though in a few cases the final value was rounded incorrectly or was only given to one significant figure.

(ii) Many candidates were able to carry out a sensible comparison of their two C values. They calculated the percentage difference (or the ratio) between their values and then decided whether the difference fell within a numerical tolerance that they chose and stated. Candidates should be discouraged from giving general statements such as 'this is valid because the values are close to each other' as these cannot be awarded credit.

(f) Stronger candidates identified problems associated with carrying out this particular experiment and in obtaining readings, and gave sufficient detail of each problem and of a method of overcoming it.

Many identified the measurement of h as a problem, and successful candidates went on to include a reason ('parallax' or 'rule not vertical' were acceptable). Valid improvements were less common – 'view at right angles to the scale' was just applying good practice and did not gain credit but 'using a set square to make the rule perpendicular to the bench' was accepted.

The difficulty with timing the oscillations was due to the need to judge the moment when the oscillation had been completed. Candidates found this difficult to describe clearly: 'difficult to see the oscillations' was not specific enough and was not awarded credit. Some candidates suggested viewing a video recording made with a timer in view, and this was accepted as a valid improvement.

Unwanted types of oscillation (swinging or vertical movements) were listed by stronger candidates, but very few workable improvements were suggested.

Movement at the joints between springs (in spite of the tape) was included by some candidates, and they usually went on to suggest an improved fixing method or the use of single, long springs.

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. Candidates should be encouraged to write about four different problems (perhaps relating to the different measurements undertaken or chronologically going through the experiment) stating <u>how</u> these difficulties impact on the experiment. Candidates should then try to think of associated solutions that address each of these problems.

PHYSICS

Paper 9702/33
Advanced Practical Skills 1

Key messages

- Many candidates find it difficult to choose scales that make good use of the graph grid. The aim should be to occupy the majority of the graph grid. If less than half of the grid is occupied in one direction, the range of the corresponding axis can be halved to make better use of the grid.

- It is important that candidates always show clearly how a numerical value has been obtained. For example, in **Question 1**, where the gradient of a straight line is calculated, it is a good idea to mark both read-offs on the graph and draw lines to construct a right-angled triangle. All the steps in calculating the value of the gradient, including the read-offs themselves, should be shown. It is also helpful to determine the units of the gradient at this stage, as this will be useful for the last part of the question.

- In order to calculate the percentage (or fractional) uncertainty in a measurement, some judgement has to be made about the absolute uncertainty of the measurement. Candidates often just use the precision of an instrument being used. Estimating the absolute uncertainty should also take into account the effect of extraneous influences (e.g. draughts and changes in temperature), uncertainties in judgement (e.g. when judging the start or finish of an oscillation) and even uncertainties caused by the act of measurement itself (e.g. putting a cold thermometer into a beaker of hot liquid will cool the liquid very slightly).

- 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

(a) Many candidates stated a value of the length *L* of one paper clip with a unit, to the nearest mm and in the appropriate range. Some candidates either stated *L* to a greater precision than one mm (i.e. added zeros) or gave a value only to the nearest cm. Some candidates stated the length in metres without considering the precision e.g. 0.03 m instead of 0.030 m.

(c) Some candidates stated a value for *T* in the appropriate range and with a unit, and showed evidence of repeated timing. Many candidates did not repeat readings or measured just one oscillation. A few candidates, having measured 10*T*, did not divide their answer by 10. Some answers were in the order of 0.5 s indicating that half an oscillation was measured.

(d) Most candidates were able to collect six sets of values of *n* and *T* without any assistance from the Supervisor. In many cases the results showed a correct trend. Some results had an incorrect trend, perhaps because candidates measured *n* as the number of paper clips above the wooden rod instead of below, or because the frequency rather than period was given for *T*.

Many candidates either increased their values of *n* from the initial value or decreased them, but they needed to do both of these to make best use of the apparatus and gain credit for the range of values.

A common mistake with the column headings was to state units for *n* and √*n*. Some candidates either omitted the units or separating mark for the *T* column.

Many candidates recorded their raw values for *t* to the nearest 0.1 s or 0.01 s. Some candidates did not state the raw values of time, and provided only calculated *T* values to the nearest 0.001 s. Some candidates stated 5*T* or 10*T* in their *T* column for period, and varied the number of decimal places down the column.

Most candidates calculated values for √*n* correctly. The question asked candidates to use three significant figures for values of √*n*. Many candidates used one, two or more than three significant figures.

(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. Candidates should be encouraged not to compress the scale to include the origin.

There were many incidences of candidates using incorrect numerical scales, often with a change in power of ten e.g. 0.8, 0.9, 1.0, 2.0. Some candidates set the axes with a minimum and maximum based on the minimum and maximum values in the table e.g. √*n* = 2.45 as a minimum and √*n* = 3.32 as a maximum. This should be discouraged as it gives a scale that is very awkward to use.

A few candidates plotted the wrong graph (*T* versus *n*) or omitted any 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 (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 lost credit for lines that were kinked in the middle (candidates used too small a ruler), by drawing a double line (broken pencil tip) or by drawing freehand lines 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 needed also to check that the triangle for calculating the gradient was large enough (the hypotenuse should be greater than half the length of the line drawn).

Some candidates were able to read off the y-intercept correctly at $x = 0$ directly from the graph. Many candidates incorrectly read off the y-intercept when there was a false origin.

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

(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).

(g) Candidates found this question difficult. Many candidates stated L in cm and substituted this into the equation but stated a final value of g in $m\,s^{-2}$. It was common for the units to be omitted or incorrect (e.g. $m\,s^{-1}$). A few candidates rearranged the equation wrongly and forgot to square the π.

A small number of candidates stated $9.81\,m\,s^{-2}$ without any working. This could not be awarded credit if it was not obtained using the values from **(a)** and **(f)**.

Question 2

(a) Most candidates measured values of A in the appropriate range and provided a unit. Some candidates omitted units. A few candidates stated A as being greater than or equal to 100 cm.

(b)(ii) Most candidates measured all raw values of x to the nearest mm.

(c)(iii) The majority of candidates stated a value of y which was greater than the value of x.

(iv) Most candidates correctly calculated $(y - x)$.

(v) Many candidates made too small an estimate of the absolute uncertainty in the value of $(y - x)$. It was awkward to place a ruler near to the measurement without affecting the balance point of the beam, so a reasonable estimate of the absolute uncertainty was greater than 1 mm.

Some candidates repeated their readings and correctly gave the uncertainty in $(y - x)$ as half the range, but some candidates did not halve the range.

A few candidates calculated percentage uncertainty in separate x and y values and incorrectly added these together rather than considering $(y - x)$.

(d)(i) Many candidates correctly calculated $m(A - 2y)$ using the same units for A and y.

(ii) Candidates found it difficult to justify the number of significant figures they had given for the value of $m(A - 2y)$. Many candidates gave reference to just 'raw readings' without stating what the raw readings were, or related the significant figures used to just one or two of the individual quantities.

(e)(i) Most candidates recorded a second value of y which was greater than the first value with the smaller mass.

(f)(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 to $k = (y - x)m(A - 2y)$ instead of $(y - x) / m(A - 2y)$. Some candidates used m twice in their multiplication calculation, effectively using m^2 instead.

(ii)   Some candidates calculated the percentage difference between their two values of *k*, and then tested it against a specified numerical percentage uncertainty. Candidates using a very large criterion needed to justify why they thought this was appropriate. Many candidates did not give a criterion. Candidates should be discouraged from giving general statements such as 'this is valid because the values are close to each other' as these cannot be awarded credit.

(g)   A few candidates obtained unrealistic values e.g. 98 000 g. These values often arose because candidates converted their values of mass from grams into kilograms previously and then did not convert back in this section when *B* was given in grams.

(h)   Many candidates recognised that two sets of data were insufficient to draw a valid conclusion. Other commonly stated problems included 'difficult to balance rule', 'difficult to measure *x* (or *y*) because the markings were obscured by the string' or 'large uncertainty in $(y - x)$'.

Candidates should take care not to re-state the same problem several different ways or provide multiple solutions to the same problem. In this particular experiment, many candidates gave the limitation as 'difficulty in balancing rule' but then expressed this same limitation in several different ways and did not gain further credit for these.

Credit is not given for suggestions that could be carried out in the original experiment, such as 'repeat measurements' or 'ensure reading is taken perpendicularly'. Vague or generic answers such as 'difficult to measure length' (without stating which length and why it is difficult), 'too few readings' (without stating a consequence), 'ruler twisting or swinging' (without stating a consequence) etc. could not be given credit. The suggestion 'fix the ruler to stop it moving' missed the point of the experiment and again could not be given credit.

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

PHYSICS

Paper 9702/34
Advanced Practical Skills 2

Key messages

- Many candidates find it difficult to choose scales that make good use of the graph grid. The aim should be to occupy the majority of the graph grid. If less than half of the grid is occupied in one direction, the range of the corresponding axis can be halved to make better use of the grid.

- It is important that candidates always show clearly how a numerical value has been obtained. For example, in **Question 1**, where the gradient of a straight line is calculated, it is a good idea to mark both read-offs on the graph and draw lines to construct a right-angled triangle. All the steps in calculating the value of the gradient, including the read-offs themselves, should be shown. It is also helpful to determine the units of the gradient at this stage, as this will be useful for the last part of the question.

- In order to calculate the percentage (or fractional) uncertainty in a measurement, some judgement has to be made about the absolute uncertainty of the measurement. Candidates often just use the precision of an instrument being used. Estimating the absolute uncertainty should also take into account the effect of extraneous influences (e.g. draughts and changes in temperature), uncertainties in judgement (e.g. when judging the start or finish of an oscillation) and even uncertainties caused by the act of measurement itself (e.g. putting a cold thermometer into a beaker of hot liquid will cool the liquid very slightly).

- 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

(a) (v) Most candidates recorded a value for T that was in the appropriate range. A few candidates either misread the stopwatch, recording values of T such as 0.001 s, or recorded the value for 10 oscillations but forgot to divide the answer by 10.

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 5 complete oscillations should be repeated two or three times, and a mean value calculated. All working should be shown, including the value of n, where n is the number of oscillations.

(b) Almost all candidates recorded six values of M, h and T correctly, showing the correct trend (T should increase as h decreases).

Some candidates chose values of M to give the widest possible range of values. Others needed to select values <u>both</u> below and above the value for M in **(a)(iii)**. A minimum value of 200 g or less and a maximum value of 450 g or more were required. In any experiment, it is good practice to try to include both the smallest and largest values possible.

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 weaker candidates recorded the units for T^3 as s rather than s^3.

Most candidates recorded all their values of h to the nearest 0.1 cm. A few candidates recorded h only to the nearest cm, or added a zero to all their values. Raw readings of a quantity should all be recorded to the same number of decimal places (depending on the precision of the instrument being used) and not necessarily to the same number of significant figures.

Almost all candidates were able to calculate the values of T^3 correctly. A few candidates calculated T^2, rounded their values incorrectly, or added an extra zero to a previously correctly rounded value.

(c) (i) Candidates were required to plot a graph of T^3 on the y-axis against h on the x-axis. Most candidates gained credit for drawing appropriate axes, with labels and sensible scales. Others chose extremely awkward scales, making the correct plotting of points much more difficult. Some chose the highest and lowest values in their tables as the lowest and highest points on their graph scales and then calculated intermediate values. This makes it very difficult to plot the points correctly. A few candidates chose non-linear scales, or scales which meant that one or more points were off the graph grid.

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

Most candidates plotted their points on the graph paper carefully. Others needed to draw the plotted points so that the diameters of the points were equal to, or less than, half a small square. Some candidates plotted points as dots or crosses that were too small to see clearly, or were hidden by the line of best fit (a small but clear pencil cross, or a point with a circle, is recommended). Some candidates could improve by plotting the points more accurately, i.e. to within half a small square.

Most 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 drew a line that 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 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 $\Delta x / \Delta y$). Candidates needed also to check that the triangle for calculating the gradient was large enough (the hypotenuse should be greater than half the length of the line drawn). Some candidates omitted the minus sign from their answer.

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. A value for the gradient without any working showing how it was obtained cannot be awarded credit.

Several candidates tried to read the value of the intercept directly from the graph. This is only a valid method if the scale in the h direction actually starts at zero – i.e. is not a 'false origin', where the origin may have been labelled '0' but its true value is different. In this experiment, beginning the h scale at $h = 0$ would mean that the plotted points would all be compressed into a narrow portion of the graph paper.

Some candidates correctly substituted a read-off into $y = mx + c$ to determine the y-intercept. Others needed to check the point chosen was actually on the line. A point from the table can only be used if it lies on the line of best fit.

(d) Most candidates recognised that a was equal to the value of the gradient and b was equal to the value of the intercept calculated in **(c)(iii)**.

The majority of the candidates recorded correct units for a (e.g. $s^3 cm^{-1}$) and b (s^3). Others omitted the units for a and b.

Question 2

(a) Most candidates recorded a value for x_0 to the nearest mm. Some recorded a value only to the nearest cm, and a few added an extra zero to their value, implying that their measurement was to the nearest 0.1 mm.

(b)(ii) Almost all candidates were able to record a value for x that was larger than x_0.

(iii) Most candidates recorded a value for ϕ in the correct range, though some stated a value with an unjustified level of precision. A few candidates recorded the supplementary angle ($180° - \phi$).

(v) Most candidates were familiar with the equation for calculating percentage uncertainties but used their value of ϕ, rather than ($\phi - 90°$), as the denominator in their calculation. Others underestimated the absolute uncertainty in the value of ($\phi - 90°$), using values of 1° or less. Given the difficulty of aligning the protractor in the correct position and holding it steady, a more realistic value for the absolute uncertainty in ($\phi - 90°$) is 2–5°.

(c)(ii) Almost all candidates recorded second values for x and ϕ. Most also found that x and ϕ were larger than the earlier values. Some candidates misinterpreted the instructions, moving the paper clips back to a distance 3 cm from the nail rather than moving the paper clips 3 cm further along the wooden strip.

(d)(i) Most candidates were able to calculate the two values for k correctly. Some substituted their first value for x in place of x_0 in the calculation, or calculated $1 / k$.

(ii) Very few candidates answered this question correctly. Most candidates were aware that the number of significant figures for k is determined by the significant figures of the 'raw data' used for calculating k, but did not state explicitly what these were. In this experiment, the significant figures of k are dependent on the significant figures of ϕ, x_0 and x or, more correctly, on ($\phi - 90°$) and ($x - x_0$).

(iii) 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 **(b)(v)** 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.

(e) (ii) Most candidates recorded values for D and d to the nearest mm, though some answers were given to the nearest 0.1 mm, or rounded to the nearest cm.

(iv) Almost all candidates calculated ρ correctly, though some substituted the first value for k into the equation rather than the second value. In calculations, values should be substituted without any rounding. Any rounding of values should be restricted to the final answer.

(f) Many candidates recognised that two sets of data were insufficient to draw a valid conclusion, though some confused conclusions with results. In this experiment, it was difficult to adjust the position of the paper clips finely enough so that the wooden strip was parallel to the bench (a 'delicate touch' was needed). However, *judging* whether or not the strip was horizontal/parallel to the bench was straightforward: the plumb line meant this could be determined 'by eye' relatively easily.

Some candidates simply described measurements that were difficult to make without explaining why they were difficult e.g. 'it was difficult to measure the angle'. More detailed answers such as 'ϕ was difficult to measure because of parallax error' or 'because it was difficult to align the protractor in the correct position and hold it steady' would have gained credit.

Many candidates recognised the large uncertainty in trying to measure the inner and outer diameters of the tube with a 30 cm ruler (or a metre rule) and some identified that ($\phi - 90°$) was small and the (percentage) uncertainty was correspondingly large.

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

Key Messages

- Many candidates find it difficult to choose scales that make good use of the graph grid. The aim should be to occupy the majority of the graph grid. If less than half of the grid is occupied in one direction, the range of the corresponding axis can be halved to make better use of the grid.

- It is important that candidates always show clearly how a numerical value has been obtained. For example, in **Question 1**, where the gradient of a straight line is calculated, it is a good idea to mark both read-offs on the graph and draw lines to construct a right-angled triangle. All the steps in calculating the value of the gradient, including the read-offs themselves, should be shown. It is also helpful to determine the units of the gradient at this stage, as this will be useful for the last part of the question.

- In order to calculate the percentage (or fractional) uncertainty in a measurement, some judgement has to be made about the absolute uncertainty of the measurement. Candidates often just use the precision of an instrument being used. Estimating the absolute uncertainty should also take into account the effect of extraneous influences (e.g. draughts and changes in temperature), uncertainties in judgement (e.g. when judging the start or finish of an oscillation) and even uncertainties caused by the act of measurement itself (e.g. putting a cold thermometer into a beaker of hot liquid will cool the liquid very slightly).

- 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

(a) (iii)   Many candidates stated a value of the distance x from the midpoint of the wire to the centre of a sphere with a unit, to the nearest mm and in the appropriate range. Some candidates either stated x to a greater precision than one mm (i.e. added zeros), or gave a value only to the nearest cm. Some candidates stated the distance in metres without considering the precision, e.g. 0.1 m instead of 0.100 m.

(b) (ii)   Some candidates stated a value for T and showed evidence of repeating n oscillations where $n \geqslant 5$. Many candidates did not repeat readings of nT or measured just one oscillation. A few candidates measured $10T$ but then provided this as the answer for T.

(c)   Most candidates were able to collect six sets of values of x and T without any assistance from the Supervisor, and in many cases the results showed a correct trend. Those candidates who showed an incorrect trend perhaps measured x as the distance from the end of the wire to the midpoint of the sphere, or worked out the frequency instead of the period T.

Many candidates increased their values from x = 12.5 cm without going lower, or decreased the values from x = 12.5 cm without extending higher. Candidates should be encouraged to use the whole range of the available equipment.

Many candidates were awarded credit for using the correct column headings in their tables. Some candidates omitted the unit for x^2 or stated an incorrect unit e.g. m.

Many candidates recorded their raw values for t 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. Some candidates stated $5T$ or $10T$ in their T column for period.

Most candidates recorded their calculated values for x^2 to the same number of significant figures as in x (or one more) and gained credit. Many candidates either stated too many significant figures or gave the calculated value to too few significant figures.

Most candidates calculated values for x^2 correctly.

(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. Candidates should be encouraged not to compress the scale to include the origin.

Some candidates set the axes with a minimum and maximum based on the minimum and maximum values in the table e.g. x^2 = 156 as a minimum and x^2 = 506 as a maximum. This should be discouraged as it gives a scale that is very awkward to use. Scales based on multiples of 3, 7 etc. are also very difficult to use and cannot be awarded credit.

A few candidates plotted the wrong graph (e.g. T versus x) or omitted any 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 lost credit for lines that were kinked in the middle (candidates used too small a ruler), by drawing a double line (broken pencil tip) or by drawing freehand lines without the aid of a ruler.

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(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 needed also to check that the triangle for calculating the gradient was large enough (the hypotenuse should be greater than half the length of the line drawn).

Candidates should check that the sign of their gradient (positive or negative) matches the graph drawn.

Some candidates were able to read off the y-intercept correctly at $x = 0$ directly from the graph. Many candidates incorrectly read off the y-intercept when there was a false origin.

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

(e)   Many candidates recognised that P was equal to the gradient and Q was equal to the intercept calculated in **(d)(iii)**, and recorded their values with consistent units for P ($s\,m^{-2}$) and Q (s). Some candidates stated incorrect units e.g. P ($s\,m^2$) or Q ($s\,m$) and others omitted units.

(f) (iii)   Some candidates gained an answer using the graph to find the x value corresponding to T in **(f)(ii)**. More candidates used the equation and their values of P and Q from **(e)** to work out x. Both methods gained credit.

Question 2

(a)   Many candidates stated a value of the length L of one spring with a unit and in the appropriate range.

(c) (ii)   The majority of candidates stated a value of y which was greater than the value of L. Some candidates either stated y to a greater precision than one mm (i.e. added zeros) or to the nearest cm. Some candidates stated the distance in metres without considering the precision e.g. 0.09 m instead of 0.090 m.

(iii)   Most candidates measured θ.

(d)   Some candidates were familiar with the equation for calculating percentage uncertainty, although many candidates made too small an estimate of the absolute uncertainty in the value of θ, typically 1° (the smallest reading). It was awkward to place a protractor near to the measurement and line it up, so a realistic estimate would have been greater than 1°.

Some candidates repeated their readings and correctly gave the uncertainty in θ as half the range while other candidates did not halve the range.

(e) (i)   Most candidates correctly calculated $(y - L)$.

(ii)   Many candidates correctly calculated $\cos(\theta/2)$.

(iii)   Many candidates correctly justified the number of significant figures they had given for the value of $\cos(\theta/2)$ giving reference to the number of significant figures used in θ. Some candidates gave reference to just 'raw readings' without stating what the raw readings were.

(f)   Most of the candidates recorded a second value of y and θ such that their second value of θ was greater than the first value of θ taken with the smaller distance d between the coils on the stand.

(g) (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 to calculate k incorrectly, using $k = (y - L)/\cos(\theta/2)$ instead of $k = (y - L)\cos(\theta/2)$.

(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 as long as the

value was a reasonable reflection of the percentage uncertainty of this experiment, but very large criteria needed to be fully justified. Many candidates omitted any criterion. Some candidates referred back to the percentage uncertainty calculated for θ and this was given credit. However, although some candidates referred back, they sometimes did not actually use the value in their comparison. Candidates should be discouraged from giving general statements such as 'this is valid because the values are close to each other' as these cannot be awarded credit.

(h)   Many candidates recognised that two sets of data were insufficient to draw a valid conclusion. Other commonly stated problems by the candidates included 'difficult to balance rule', 'difficult to measure y (or θ) because of parallax error' and 'difficult to keep 15 cm the same as my hands were shaking'. The latter point was also valid in the measurement of y or θ. Common acceptable solutions were 'take more readings and plot a graph' and 'use another stand to hold the protractor steady'.

Credit is not given for suggestions that could be carried out in the original experiment, such as 'repeat measurements' or 'ensure reading is taken perpendicularly'. Vague or generic answers such as 'difficult to measure θ or y' (without stating why it is difficult), 'too few readings' (without stating a consequence), 'parallax error' (without stating which reading is affected) etc. could not be given credit.

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

PHYSICS

Paper 9702/41
A Level Structured Questions

Key messages

- Candidates should take care when using specialist vocabulary. For example, they should be careful with words such as atom/molecule/particle, nucleus/nucleon, energy/power, speed/velocity etc. These words have similar but not identical meanings, and the use of an incorrect word can often mean that a candidate cannot be awarded credit for part of an explanation.

- Many candidates correctly answer questions on small sections of the syllabus, but they have difficulty where it is necessary to gather together information in answering questions that require application and extension. Candidates should be encouraged to develop links between different parts of the syllabus and they may benefit from further practice using previous question papers.

- In questions requiring explanations, candidates should be encouraged to give more detail, as often they do not give enough detail for full credit to be awarded.

- Some questions give an instruction such as "use your answer from..." To be awarded full credit for the answer, it is essential that the instruction is followed. Candidates should be encouraged to read the question carefully and follow any specific instructions relating to the required answer.

General comments

Many candidates are better at recalling information learnt by rote than at applying principles to new situations. They should take care to read the question carefully before beginning to answer, as some descriptions given were not related to the question being asked (for example, CT scanning being discussed instead of NMRI in **Question 8**).

There was no evidence to suggest that well-prepared candidates did not have sufficient time to complete their answers.

Comments on specific questions

Question 1

(a)   A large number of candidates found it difficult to express well the idea that the gravitational force of attraction between the planet and the satellite provides the centripetal force. Some quoted Newton's law of gravitation in words and others described a geostationary orbit.

(b)   This was a difficult question and it is a credit to the mathematical abilities of the candidates that many of them were able to produce correct answers. The most common mistakes were to use R instead of nR or not to square (or cube) both of the letters, i.e. $(nR)^3$ was correct but nR^3 was not. Some candidates could improve by presenting their work more clearly.

(c)   Weaker candidates did not understand the ratio n of the two radii and used one radius or the difference between them instead. Many candidates made the mistake of not squaring the time period.

Question 2

(a)   Determining the frequency was straightforward, but some weaker candidates could not obtain the time period from the graph.

(b)   The nature of the damping was again, straightforward. A significant number of candidates thought this was heavy or critical damping.

(c)   Candidates need to make clear whether they are using total energy, kinetic energy or potential energy in their working. The kinetic energy is zero at the two times given because the magnet is at its maximum displacement in each case. Candidates should also take care to use consistent symbols in equations. For example, some candidates used symbols for one amplitude and one displacement rather than two amplitudes.

In questions where the phrase 'explain your working' is used, candidates should ensure that they show the origin of the data they use. In order to gain full credit, candidates needed to clearly identify the amplitude obtained from the graph at each time stated. Many candidates did not do this.

Question 3

(a) (i)   Most candidates were able to state what is meant by a digital signal.

(ii)   Most candidates could correctly names components X and Y.

(iii)   Many candidates described the function of the ADC by saying it converts analogue signals to digital signals, but did not give any detail about how this process takes place. The key physics point here is that the ADC samples the signal at regular intervals and then converts it.

(b) (i)   Candidates found this question difficult. If the signal-to-noise ratio at the output is 28 dB then it must be greater at the input because the noise is constant along the cable. Indeed, it must be greater by the amount that the signal has been attenuated by travelling along the cable, which is 16 dB. Very few candidates achieved full credit, but many candidates were awarded partial credit for multiplying the attenuation per unit length of the fibre by the length of the fibre.

(ii)   Candidates were slightly more successful at this question. The majority of candidates, even weaker ones, at least knew that attenuation in dB = 10 lg (P_1 / P_2). Of these candidates, many could use the formula correctly to calculate an output signal power of 2.5×10^{-4} W and so gain some credit. The stronger candidates went on correctly to calculate the noise power using the expression noise power = output power / $10^{2.8}$.

Question 4

(a)   Most candidates stated that the motion is random but did not give any further information. The question required reference to molecules and candidates should be discouraged from talking about movement of 'the gas' when they mean to describe the molecules.

(b)   The question asked candidates to describe what is *observed* when viewing Brownian motion. Any answers referring to observing the molecules could not be awarded credit.

(c) (i)   Many candidates knew the formulae they should be using here, but they found it difficult to establish, in particular, what the mass was. Some used the total mass of the gas when they should have used the mass of one atom. Some used the mass of one atom in a formula that required the total mass of the gas. Some candidates did not take the square root at the end of their working.

(ii)   Some candidates knew that the mean-square speed is proportional to the absolute temperature but many did not know whether they should be using mean-square speed or root-mean-square speed. A small number of candidates tried to use temperature in Celsius and this could not be awarded credit. Some candidates did not use their answer from **(b)(i)** when answering **(b)(ii)**.

Question 5

(a)   The candidates who knew the formula for the electric potential energy of a charged particle near a nucleus usually gained at least partial credit for this question. It was common for candidates to provide insufficient detail to be awarded credit for the explanation. A number of weaker candidates confused the electric field strength formula for the electric potential energy formula.

(b)   Candidates who understood which equation to use generally scored highly on this question. Some candidates used the equations of motion and $W = Fd$, which are both incorrect physics (the force is not constant and the distance from the nucleus is not the distance moved).

(c)   Many candidates described absorption of the α-particle. A small number of stronger candidates realised that the foil is thin so that the α-particles interact with only one nucleus.

Question 6

(a) (i)   Although many candidates had the correct idea of a smaller current and a larger current, they did not gain full credit as they did not link these ideas to the relevant parts of the circuit.

(ii)   There were many incomplete circuit diagrams. Some candidates may have overlooked this question. A quick check of the marks in brackets [ ] when finishing each question might help candidates to check that they have not missed anything. Of those that did complete the circuit diagram, many did not know the correct symbol for the relay.

(b) (i)   Many candidates were unable to explain the function of the variable resistor. It was common for candidates to state that it was to keep the current or voltage constant, which is a general use of the component rather than the specific use in this circuit. Very few realised that this would alter the light intensity at which the lamp would be switched on.

(ii)   Common uses of the diode were often stated, for example to allow current in one direction only, but candidates often did not apply its use to this circuit. Candidates did not realise that both positive and negative outputs from the op-amp would activate the relay and hence close the switch, so the diode would limit this to just the positive output.

(c)   Most candidates understood how an LDR reacts to light intensity. A misconception of weaker candidates was often that a lower resistance at higher light intensity would give a greater current and hence the lamp would light. They did not understand how the comparator would operate in this circuit.

Question 7

(a)   Many candidates provided good answers. Some referred to the field perpendicular to the velocity, rather than the force. Often candidates did not say that the force, speed or KE is constant. It is important to use physics vocabulary correctly in explanations: it is incorrect to say that the velocity is constant in this situation.

(b)   Many candidates could navigate their way through this derivation. Some incorrectly began with $Bqv = mv^2 / r$.

(c)   Most candidates realised that this part of the question was a combination of the first two parts of the question, and could obtain credit for the circular motion equation for a charged particle in a magnetic field. A common mistake after this was to confuse v (speed) and V (potential difference) and cancel them.

(d)   This was generally understood, although some candidates confused the cause and effect, stating that the radius increased and this caused an increase in momentum.

Question 8

Generally, this was a well answered question. Candidates could have improved their answers by providing more detail. In particular, they often omitted to mention a *strong/large* magnetic field, omitted the *pulse* or did not mention *RF*. Many responses did not describe the ideas of changing the position of detection or of several different slices being studied.

There were relatively many candidates who did not seem to understand NMRI and attempted to answer the question by recalling passages from textbooks. Such answers tend to contain a lot of extraneous and irrelevant information.

Question 9

(a) (i) Candidates needed to ensure that their answers were in the context of the transformer. In this context, the purpose of the iron core is not just to increase the magnetic flux, but specifically to increase the flux linkage with the secondary coil.

(ii) Candidates often used the words 'prevent' and 'stop' but the laminations can only reduce the effect of eddy currents. Most candidates realised that eddy currents were involved, but they did not always make clear where these currents appear (i.e. in the core).

(b) The answers to this type of question could be improved if candidates were careful to explain exactly where each of the processes they describe takes place. For example, the changing current in the primary coil produces a changing magnetic flux in the core, this links the secondary coil, etc.

Question 10

(a) (i) Many candidates understood that hardness of an X-ray beam is related to penetration, but not all candidates were able to explain that a harder beam had a greater penetration.

(ii) Most candidates answered this well. Some candidates vaguely described 'voltage' being increased but it would have been clearer to mention the accelerating potential difference or the potential difference between anode and cathode.

(b) This calculation was completed well. A few candidates omitted the minus sign in the power of the exponential. The weakest candidates multiplied the two sets of x and μ values and divided those values.

Question 11

(a) Many responses were vague and candidates did not always use the correct terminology. For example, candidates should avoid using phrases such as 'wavelengths of light absorbed by the gas'. It was common for electrons and photons not to be specified, and candidates often did not indicate the idea that the interaction is one-to-one. Candidates would benefit from further study of the physics of the formation of an absorption spectrum.

(b) (i) Most of the successful responses used $E = hc/\lambda$. Some candidates did not convert from J to eV so they could not be awarded full credit. Most of the candidates who used the idea of ratios incorrectly used $E \propto \lambda$.

(ii) There were few answers with all three correct lines drawn on the energy level diagram. Some candidates thought they needed to add horizontal lines for more energy levels. Many candidates did not have all three correct transitions.

Question 12

(a) The majority of candidates correctly determined that 7 electrons had been emitted.

(b)(i) This 'show that' calculation was generally carried out well, but some candidates did not make the conversion from eV to MeV clear enough.

(ii) This was a difficult calculation and candidates needed to be careful to ensure that all of the particles were included. It was common for candidates to miss out electrons, neutrons and in some cases nuclei in their calculations.

(c) Nuclear reactions transform energy to the kinetic energy of fission fragments and also gamma radiation. Candidates often mentioned macroscopic manifestations of the kinetic energy e.g. thermal, light etc.

PHYSICS

> **Paper 9702/42**
> **A Level Structured Questions**

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- Many candidates correctly answer questions on small sections of the syllabus, but they have difficulty where it is necessary to gather together information in answering questions that require application and extension. Candidates should be encouraged to develop links between different parts of the syllabus and they may benefit from further practice using previous question papers.

- In questions requiring explanations, candidates should be encouraged to give more detail, as often they do not give enough detail for full credit to be awarded.

- Some questions give an instruction such as "use your answer from..." To be awarded full credit for the answer, it is essential that the instruction is followed. Candidates should be encouraged to read the question carefully and follow any specific instructions relating to the required answer.

General comments

Candidates generally found it much easier to gain credit for numerical parts of questions than for descriptive sections. Descriptive answers often contained irrelevant information. Candidates would benefit from further practice at giving responses to questions that are qualitative in nature rather than quantitative.

There was no evidence to suggest that well-prepared candidates did not have sufficient time to complete their answers.

Comments on specific questions

Question 1

(a)   In general, a correct definition was given. Credit was not given where the ratio of force and mass was not made clear. A small minority either defined gravitational potential or described a gravitational field.

(b)(i)   Generally, this calculation was completed successfully. A minority gave the correct expression for g but then, on substitution, either did not square r or left the radius in km.

(ii)   Most candidates calculated the mass of the probe and then correctly multiplied this mass by the answer in **(b)(i)**. A small number of candidates arrived at implausible answers which were left without comment. Candidates who obtain unusual answers should be encouraged to check their working as this may reveal an error.

(c)   Candidates found it difficult to describe the features of the fields.

The similarity was often described in terms of *forces* rather than *fields*. A common misconception was that, for both comets, the field would follow an inverse square law with distance. Very few

gave the similarity as the direction of the field being towards the comet. Candidates who referred to direction usually thought that this would be towards the centre of the comet.

A common misconception for the difference was to describe the fields as being 'uniform' and 'non-uniform'. Where candidates referred to the field as being 'constant' or 'not constant', the fact that this would be over the surface was rarely included.

Question 2

(a) (i) The majority of answers were correct. Some referred to either 'square of the mean' or to 'root-mean-square'. There were some weaker candidates who confused c with the speed of light or with specific heat capacity.

(ii) In most scripts, there was a correct statement of either the expression $pV = nRT$ or the expression $pV = NkT$. Those who then gave the density as Nm/V were, in general, successful. Many gave the density as M/V and then set $N = 1$ to obtain the given expression.

A minority provided the correct solution but did not complete the derivation by equating E_K and $\frac{1}{2}m\langle c^2 \rangle$.

(b) (i) Only the strongest candidates identified the link between the energy required to change the temperature at constant volume and the change in kinetic energy.

Many candidates were unable to use the expression given in **(a)(ii)** for the kinetic energy of one molecule to obtain the kinetic energy of N_A molecules. Setting $N_A = 1$ was a common procedure to obtain the given answer.

(ii) The majority of answers were correct. The most common error was a power-of-ten error for the molar mass.

Question 3

(a) (i) Most answers were correct although a minority did not give the answer to two significant figures, as specified in the question.

(ii) The majority of candidates gave an appropriate expression for the energy of the oscillations. Substitution into the formula produced a large number of errors. Some candidates did not give mass in kg and amplitude in metres, and many did not square appropriate terms.

A small minority calculated the correct answer but then multiplied by 2.5 (the number of 'free' oscillations).

(b) (i) The majority of statements were correct. Some referred, incorrectly, to induced current rather than induced e.m.f. or did not consider *rate of change*.

(ii) Candidates found it difficult to give comprehensive answers. Some candidates did give a satisfactory explanation as to the coil cutting the flux of the magnet, hence inducing an e.m.f. in the coil. Many described the magnet cutting the flux of the coil, and inducing eddy currents in either the magnet or the coil.

Of those candidates who explained the origin of the current in the circuit, very few then went on to describe the production of thermal energy in the resistor and the reduction in amplitude of the oscillations. Most descriptions were based on Lenz's law with a force opposing the motion of the magnet. This did not involve the reference to energy conservation required by the question.

Question 4

(a) A significant number of candidates were able to describe the source of the ultrasound and that the waves are reflected from boundaries. Some candidates mentioned that the ultrasound is pulsed and that the reflected pulses are detected by the transmitter. A much smaller number were able to state how information about the depth and nature of boundaries is obtained from the reflected pulses. Some made a reference to a gel but very few gave the reason for its use.

Some candidates who wrote long answers were given little credit because they described properties of ultrasound, how ultrasound is produced and the advantages and applications of ultrasound. A significant minority combined features of ultrasound, CT scans and NMRI in their accounts, and this irrelevant material could not be awarded credit.

(b)   There were many correct answers. Weaker candidates found it difficult to give a correct expression. In particular, the ratio I/I_0 was often inverted or the negative sign in the exponential was omitted.

Question 5

(a)   Many candidates made a reference to removal of noise or regeneration. Candidates should be careful not to say that digital signals contain 'no noise'. There is noise but the important feature is that it can be removed by regeneration.

(b)(i)   The essential starting point for a correct answer was to state that the analogue signal would be sampled and that this would be at regular intervals. Many answers included only the conversion of an analogue signal to a digital form, which did not add further information to that provided in the question.

(ii)   Most answers considered only the quality of the signal. Answers where step depth/width and step height were mentioned were relatively rare.

Question 6

(a)   Many answers did not have enough precision. Many referred to 'force between charges', without any qualification i.e. 'two point charges'. Others were not awarded credit because they did not include the *product* of the charges or referred to the separation rather than the *square* of the separation.

(b)(i)   There were many comments on the value of *E* changing from positive to negative but this was rarely used to explain that the fields due to the two charges must be in opposite directions. Some realised that the zero point meant that there is no resultant field at that point, but then made the incorrect conclusion about the sign of the charges.

(ii)   There were many scripts where the acceleration was determined successfully, with adequate explanation. A significant minority attempted either to use Coulomb's law to determine the charges on the spheres or to use an expression for constant electric field to determine a potential difference.

(c)   Candidates often gave either the point where the field strength is zero or the point where the field strength changes most rapidly. Stronger candidates related field strength to potential gradient and then reached the correct conclusion.

Question 7

(a)   Very few candidates explained that there is no net charge stored by a capacitor. This may be because, as later seen in **(b)**, they defined capacitance in terms of energy stored. Few candidates referred to work done to separate the charges of different sign. A common misconception was that energy is required to maintain the separation.

(b)   Most candidates gave the ratio of charge and potential in some form. Very few gave the detail of where the charge is located and between which two points the potential difference is maintained.

(c)   The majority of candidates gave a correct answer. This was seen where the expression energy = $\frac{1}{2}CV^2$ was quoted. A common error was to quote energy = $\frac{1}{2}QV$ and then to assume that the charge would be constant.

Question 8

(a) (i)   In a significant number of scripts, only one LED had been circled.

    (ii)   Most answers included some reference to a comparator but only stronger candidates gave a complete answer fully in context, with mention of temperature.

(b) (i)   There were many full answers to this part of the question. In some, the fact that the output would be negative was omitted. Others did not describe the difference in potentials between the inverting and non-inverting inputs. A small minority described the potentials in reverse and concluded that blue light would be emitted.

    (ii)   Some answers described very clearly the switch-over as the resistance is changed. It was common to find answers that did not indicate that the green LED would switch off. A small number wrote about a red light, possibly indicating that they had attempted to learn an answer to this type of question.

(c)   Candidates found it difficult to answer in the context of the question. Many candidates described applications of variable resistors in general such as circuit protection from current overload.

Question 9

(a) (i)   There were many varied attempts to explain why the slice should be thin, and the misconceptions showed that candidates would benefit from further study of the Hall effect. There were many irrelevant answers.

    (ii)   Very few answers related the current in the slice to the Hall voltage. A common answer was that the current in the slice affects the flux density in the solenoid. It was uncommon to see a distinction made between the flux density in the solenoid and the reading of the flux density on the probe.

(b)   There were some well-drawn curves but many were not one cycle of a sinusoidal wave. A significant number of candidates were given partial credit for values at the start, the end and the midpoint of the curve but the shape was incorrect.

Question 10

(a)   Although stronger candidates showed a clear understanding of the topic, others did not demonstrate their understanding of the photoelectric effect. Some weaker candidates included ideas from completely different fields of physics.

    Many candidates did not refer to what is emitted. Of those who referred to kinetic energy of electrons, many did not appreciate that the maximum kinetic energy is the crucial factor. Several wrote about an increase in photoelectric current with increase in intensity.

(b) (i)   Some weaker candidates wrote 'maximum wavelength' without giving any further explanation, and this could not be credited. Others gave a full answer but gave the wavelength as the minimum.

    (ii)   **1.** Although the majority of answers were correct, a significant number of candidates gave either the intercept or the end point of the line as the answer.

           2. Most candidates were able to calculate the gradient. Weaker candidates assumed that this would be the Planck constant, but most candidates did correctly equate the gradient to hc. A common error was to omit the powers of ten when reading the graph.

(c)   A large number of candidates did not attempt to draw a line. Some drew a line parallel to the given line but the intercept was often incorrect.

Question 11

(a)   There were many clear derivations with adequate explanation.

(b)(i)   The majority of candidates could quote the relevant equation. Some did not appear to appreciate that the wave is associated with a moving particle.

(ii)   There were many complete answers with candidates using the equation for momentum given in **(a)**. A common answer from weaker candidates was to assume the momentum would be *mc*, where *c* is the speed of light.

(c)   Candidates found this question difficult. There were very few acceptable answers, with many writing 'the waves just pass through' without making reference to diffraction.

           A significant minority of candidates were not able to compare two numbers when expressed in standard form, possibly as a result of the negative indices. Very few stated that the wavelength and the separation are of the same order of magnitude.

Question 12

(a)   The great majority of answers were correct. The most common problem was the omission of the number of emitted electrons. Some wrote the number 7 as a subscript or the superscript.

(b)(i)   There were many correct solutions. Some candidates did not appreciate the starting point for the calculation or used the nuclear reaction given in the question.

(ii)   The majority of candidates did not demonstrate that they understood how to obtain the required difference in mass. Consequently, there were very few correct answers.

(c)   Candidates found this question difficult. They were divided equally as to whether the binding energy per nucleon would be greater or less. The most common approach was to consider the stability of the nuclei, but there was rarely enough explanation to give the answer full credit.

PHYSICS

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(d)   This was generally understood, although some candidates confused the cause and effect, stating that the radius increased and this caused an increase in momentum.

Question 8

Generally, this was a well answered question. Candidates could have improved their answers by providing more detail. In particular, they often omitted to mention a *strong/large* magnetic field, omitted the *pulse* or did not mention *RF*. Many responses did not describe the ideas of changing the position of detection or of several different slices being studied.

There were relatively many candidates who did not seem to understand NMRI and attempted to answer the question by recalling passages from textbooks. Such answers tend to contain a lot of extraneous and irrelevant information.

Question 9

(a) (i) Candidates needed to ensure that their answers were in the context of the transformer. In this context, the purpose of the iron core is not just to increase the magnetic flux, but specifically to increase the flux linkage with the secondary coil.

(ii) Candidates often used the words 'prevent' and 'stop' but the laminations can only reduce the effect of eddy currents. Most candidates realised that eddy currents were involved, but they did not always make clear where these currents appear (i.e. in the core).

(b) The answers to this type of question could be improved if candidates were careful to explain exactly where each of the processes they describe takes place. For example, the changing current in the primary coil produces a changing magnetic flux in the core, this links the secondary coil, etc.

Question 10

(a) (i) Many candidates understood that hardness of an X-ray beam is related to penetration, but not all candidates were able to explain that a harder beam had a greater penetration.

(ii) Most candidates answered this well. Some candidates vaguely described 'voltage' being increased but it would have been clearer to mention the accelerating potential difference or the potential difference between anode and cathode.

(b) This calculation was completed well. A few candidates omitted the minus sign in the power of the exponential. The weakest candidates multiplied the two sets of x and μ values and divided those values.

Question 11

(a) Many responses were vague and candidates did not always use the correct terminology. For example, candidates should avoid using phrases such as 'wavelengths of light absorbed by the gas'. It was common for electrons and photons not to be specified, and candidates often did not indicate the idea that the interaction is one-to-one. Candidates would benefit from further study of the physics of the formation of an absorption spectrum.

(b) (i) Most of the successful responses used $E = hc/\lambda$. Some candidates did not convert from J to eV so they could not be awarded full credit. Most of the candidates who used the idea of ratios incorrectly used $E \propto \lambda$.

(ii) There were few answers with all three correct lines drawn on the energy level diagram. Some candidates thought they needed to add horizontal lines for more energy levels. Many candidates did not have all three correct transitions.

Question 12

(a)   The majority of candidates correctly determined that 7 electrons had been emitted.

(b) (i)   This 'show that' calculation was generally carried out well, but some candidates did not make the conversion from eV to MeV clear enough.

   (ii)   This was a difficult calculation and candidates needed to be careful to ensure that all of the particles were included. It was common for candidates to miss out electrons, neutrons and in some cases nuclei in their calculations.

(c)   Nuclear reactions transform energy to the kinetic energy of fission fragments and also gamma radiation. Candidates often mentioned macroscopic manifestations of the kinetic energy e.g. thermal, light etc.

PHYSICS

Paper 9702/51
Planning, Analysis and Evaluation

Key messages

- 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 both for determining quantities and for determining uncertainties. A full understanding of significant figures and unit prefixes is needed.

- The practical skills required for this paper should be developed and practised over a period with a 'hands on' approach.

General comments

Most candidates completed the paper and there was no evidence of time constraints. Most of the scripts were clearly written.

In **Question 1**, candidates did not always describe the method in the necessary detail. The methods that candidates described to determine the velocity often did not have enough detail and did not mention the appropriate measurements. It is advisable that candidates should think carefully about the experiment following the points given on the question paper, and to imagine how they would perform the experiment in the laboratory. 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**, graphs were usually well drawn with points and error bars easily identifiable. Candidates should be advised that, to gain the highest marks, the presentation of mathematical working requires a clear statement of the equation used with substitution of numbers, leading to the correct answer. Clear, logical working enables candidates to complete the question successfully.

Comments on specific questions

Question 1

Candidates were required to investigate how the speed v of a wooden block at a point Q on a plane varied with the angle θ of the plane to the horizontal when the block is caused to move through a fixed distance by a falling body.

Candidates should be encouraged to spend time reading the question carefully to enable them to formulate a workable plan before starting their answer. It is important that each symbol in the given equation is understood. Candidates should then decide which quantity is the independent variable and which quantity is the dependent variable. Candidates should then consider how these variables may be measured. Some weaker candidates were confused and did not know how to proceed with the laboratory experiment.

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Candidates were awarded credit for correctly identifying the independent and dependent variables and the constant *s*, although on some occasions this contradicted what was written in their experimental descriptions. The number of candidates using the word 'control' instead of the correct word 'constant' when considering quantities to keep constant has decreased.

Credit was available for drawing a clearly labelled workable diagram. Diagrams should include the necessary pieces of apparatus set up as they would be used in the experiment. In this experiment, the inclined plane required an effective means of support with the distance *s* (PQ) clearly marked.

Candidates needed to give a method of measuring appropriate quantities. The measuring instruments must be stated. Most candidates correctly identified a method to measure the angle θ. Many candidates suggested the use of a protractor, and many stronger candidates drew the protractor on the diagram in the correct position. Other candidates suggested trigonometric methods. In these cases, candidates needed to clearly indicate the distances to be measured and how they would be measured. Credit was available for the additional detail of how $\sin \theta$ or θ would be determined from a trigonometric method.

Two marks were available for determining the speed *v* of the wooden block at point Q. Candidates suggested a variety of methods, with many opting to measure *s* with a ruler and the time with a stopwatch. Very few candidates could produce the correct formula for calculating *v*, often omitting a factor of 2 in the equation of constant acceleration and thus determining the average velocity rather than the final velocity. Candidates who chose to use light gates often forgot that a datalogger measuring time was required. A relatively small number of candidates gave a good description of a measured length of card attached to the block breaking the beam of a light gate placed at Q, followed by the relevant theory. Candidates could describe methods which used either one or two light gates. Methods using a motion sensor required the sensor to be placed in the correct position, which was best shown in the diagram. Answers for this method often did not contain detail of how to find *v*. When candidates are suggesting the use of light gates or motion sensors, a clear description of the measurements and the method is needed.

Most candidates identified a suitable graph to plot, though a few candidates suggested plotting θ instead of $\sin \theta$ or *v* instead of v^2. Candidates needed to state that the relationship would be valid if a straight line was observed on the graph. To obtain credit for determining *g*, the gradient of the graph must be used and then the expression rearranged to give *g* as the subject.

The additional detail section has a maximum of six marks that could be awarded. In general, candidates found it difficult to give enough detail to obtain these marks. 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 clearly reasoned safety precaution relevant to the experiment. A reason must be given as to why the safety precaution is selected. In this experiment, a sand box to catch the falling body would have been reasonable.

Question 2

The question required candidates to analyse data given for how the time *t* for a pulse to travel to the end of a cable and back varies with the total length *Z* being removed from the cable.

(a) Candidates were asked to determine expressions for the gradient and *y*-intercept of a graph of *t* against *Z*. A significant number of candidates answered this incorrectly.

(b) Most candidates were awarded full credit. Some candidates quoted the first value as 0.8 (one significant figure) instead of 0.80 (two significant figures).

(c) (i) Most of the candidates were awarded full credit. The points and error bars were straightforward to plot. Some candidates were not awarded credit because their plotted points were too large.

(ii)   The drawing of the straight lines was good. Many candidates use a sharp pencil and a transparent 30 cm ruler which covers all of the points. Several candidates joined the first plotted point to the last plotted point, and this did not give the line of best fit. Candidates should be advised to take care drawing the line of best fit, balancing the position of the plotted points on each side of the line. Generally, the worst acceptable line was drawn well. 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 when calculating the gradient and not data points from the table.

(iv)   Some candidates correctly read the y-intercept from the drawn lines on the graph. Other candidates substituted points into $y = mx + c$. Evidence for the value of the uncertainty was required by subtraction of the y-intercepts from the line of best fit and worst acceptable line. 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 only be done if the crossing point is used), or to use the gradient of the line of best fit.

(d) (i)   Candidates who had correctly stated the expressions for the 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)   This question was well answered, particularly by candidates who used the method of combining percentage uncertainties in the gradient and intercept. It is essential that candidates show their working. Some candidates found the uncertainties in v and L using maximum and minimum methods, but often the working for this method was unclear. Those candidates who attempted to calculate the maximum and minimum values for L tended to make mistakes by using incorrect combinations of maximum and minimum values.

PHYSICS

> **Paper 9702/52**
> **Planning, Analysis and Evaluation**

Key messages

- 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 both for determining quantities and for determining uncertainties. A full understanding of significant figures and unit prefixes is needed.

- The practical skills required for this paper should be developed and practised over a period with a 'hands on' approach.

General comments

Most candidates completed the paper and there was no evidence of time constraints. Most of the scripts were clearly written.

In **Question 1**, candidates did not always describe the method in the necessary detail. The methods that candidates described to determine the measurement of frequency were often incorrect, and there were many inappropriate references to a cathode-ray oscilloscope for this purpose. Many candidates did not realise that they needed to increase the frequency slowly until the cube was just seen to move. 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**, graphs were usually well drawn with points and error bars easily identifiable. Candidates should be advised that, to gain the highest marks, the presentation of mathematical working requires a clear statement of the equation used with substitution of numbers, leading to the correct answer. Clear, logical working enables candidates to complete the question successfully.

Comments on specific questions

Question 1

Candidates were required to investigate the relationship between the distance *r* and the maximum frequency *f* of a turntable for which the cube does not move relative to the turntable. Some candidates did not read the question and designed experiments with the cube glued/taped to the turntable to prevent it from moving.

Most candidates gained credit for identifying the dependent and independent variables. A mark was awarded for stating that *m* needed to be kept constant. There was an additional detail mark for stating that the mass of the cube needed to be measured with a balance. Candidates should be encouraged not to use the imprecise term 'a scale' to describe the instrument for measuring mass.

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Credit was available for a correct, labelled diagram indicating that the turntable was connected to a motor with a correct circuit diagram. A common mistake was to draw signal generators and cathode-ray oscilloscopes in series with power supplies. Candidates needed to indicate how the frequency of the turntable could be varied. It was expected that that candidates would vary the current through the motor. Many candidates incorrectly suggested using a cathode-ray oscilloscope to vary the frequency.

Candidates could gain credit for explicitly stating how the maximum frequency could be determined. Stronger candidates stated that they would gradually increase the frequency until the cube was observed to move.

The final mark for data collection was for the method of determining the frequency of rotation of the turntable. Many candidates suggested timing the period of rotation using a stopwatch, and further credit was available for the additional detail of timing ten or more rotations and then finding the reciprocal of the period.

The majority of candidates who gained credit for the analysis of data suggested plotting a graph of f against $1/r$. Other valid alternatives such as $1/r$ against f gained credit. Similarly, appropriate logarithmic graphs gained credit. The relationship would be valid if, from the appropriate graph, a straight line passing through the origin was observed. Candidates who suggested the plotting of a logarithmic graph needed to state that the relationship would be valid if the graph was a straight line with the correct numerical gradient. Candidates also needed to explain 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.

The additional detail section has a maximum of six marks that could be awarded. In general, candidates found it difficult to give enough detail to obtain these marks. 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 precaution linked to the cube moving from the turntable was required such using as a safety screen. Many candidates suggested wearing goggles. A safety screen would be better because it would protect other people as well as the experimenter.

Question 2

The question required candidates to analyse data given for how the current I in a circuit varied with the resistance P of a resistor.

(a)   This question was generally answered well.

(b)   Most candidates obtained full credit. Some candidates gave the last value of $1/I$ as 100.0 (four significant figures) instead of 100 (two or three significant figures). A value of 100.0 was incorrect because I was given to two significant figures. Some candidates incorrectly assumed that the absolute uncertainty in the resistance values was $0.05\,\Omega$.

(c) (i)   Most of the candidates were awarded full credit for plotting the points and error bars. Some candidates were not awarded credit because their plotted points were too large, and some candidates' error bars were not equal in length above and below the point.

  (ii)   The drawing of the straight lines was good. Many candidates use a sharp pencil and a transparent 30 cm ruler which covers all of the points. Several candidates joined the first plotted point to the last plotted point, and this did not give the line of best fit. Candidates should be advised to take care drawing the line of best fit, balancing the position of the plotted points on each side of the line. Generally, the worst acceptable line was drawn well. 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 when calculating the gradient and not data points from the table.

(iv)   To find the *y*-intercept, candidates needed 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 only be done if the crossing point is used), or to use the gradient of the line of best fit.

(d)(i)   Candidates who had correctly stated the expressions for the 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)   This question was well answered, particularly by candidates who used the method of combining percentage uncertainties in the gradient and intercept. It is essential that candidates show their working. Some candidates found the uncertainties in *E* and *Q* using maximum and minimum methods, but often the working for this method was unclear. Those candidates who attempted to calculate the maximum and minimum values for *Q* tended to make mistakes by using incorrect combinations of maximum and minimum values.

PHYSICS

**Paper 9702/53
Planning, Analysis and Evaluation**

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(iv) Some candidates correctly read the y-intercept from the drawn lines on the graph. Other candidates substituted points into $y = mx + c$. Evidence for the value of the uncertainty was required by subtraction of the y-intercepts from the line of best fit and worst acceptable line. 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 only be done if the crossing point is used), or to use the gradient of the line of best fit.

(d)(i) Candidates who had correctly stated the expressions for the 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) This question was well answered, particularly by candidates who used the method of combining percentage uncertainties in the gradient and intercept. It is essential that candidates show their working. Some candidates found the uncertainties in v and L using maximum and minimum methods, but often the working for this method was unclear. Those candidates who attempted to calculate the maximum and minimum values for L tended to make mistakes by using incorrect combinations of maximum and minimum values.