PHYSICS

Paper 9702/11
Multiple Choice

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

General comments

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

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

Candidates found **Questions 9**, **27**, **33** and **38** difficult. They found **Questions 4**, **5**, **6**, **7**, **11**, **12**, **17** and **18** relatively straightforward.

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Comments on specific questions

Question 9

Candidates found this question difficult, with the majority selecting **C** rather than the correct answer **D**. A skydiver falling from an aircraft will initially accelerate. As the speed of the skydiver increases, the air resistance force opposing the motion will increase. The net force (weight minus air resistance) will decrease and so the downwards acceleration of the skydiver will also decrease.

Question 10

Candidates found this question difficult, with almost as many selecting **B** or **D** as the correct answer **C**. As this is an elastic collision, the velocity of separation of the two gliders must be the same as the velocity of approach ($3.0\,\text{m}\,\text{s}^{-1}$). This eliminates **A** and **B** as possible answers as, regardless of direction, the two speeds cannot be combined to give an answer of $3.0\,\text{m}\,\text{s}^{-1}$. The total kinetic energy before the collision (1.188 J) must be the same as the total kinetic energy after the collision. Only **C** satisfies this condition.

Question 14

Almost as many candidates selected **B** or **C** as the correct answer **A**. The simplest way to answer this question is to calculate the volume occupied by each of the three oils, add them to obtain the total volume, and then determine the density by dividing the total mass by the total volume.

Question 15

The majority of candidates answered this question correctly. A significant number selected **A** rather than **D**, incorrectly multiplying the output power by 0.6 to obtain a value of 72 W for the input power.

Question 19

Most candidates realised that the value of the spring constant of the spring could be found by calculating the force per unit extension from the graph, though some candidates omitted to convert the extension from cm to m in order to obtain the correct value for the spring constant in $\text{N}\,\text{m}^{-1}$.

Question 21

The majority of candidates recognised that the displacement of particle X is zero at time $t = 0$, eliminating graphs **B** and **D**. As the wave is moving to the right, the initial movement of particle X must be downwards, making **C** the correct answer.

Question 24

Most candidates recognised that the police car must be moving towards the observer in order for the observer to hear a frequency higher than the frequency of sound emitted by the police car. Some candidates confused the values of the frequency emitted by the source with the frequency heard by the observer when substituting values into the equation for the Doppler effect.

Question 26

Each wave pulse will have moved 1.5 m further along in a time of 3.0 s. If the new positions of the two waves are drawn on the diagram, they can be seen to overlap completely (complete constructive interference) confirming **C** as the correct answer.

Question 27

The majority of candidates found this question difficult. Most recognised correctly that the wavelength of the waves passing through the gap would be unaffected by increasing the width of the gap. However, as the difference between the size of the gap and the wavelength of the waves increases, the amount of diffraction that occurs will decrease (θ must decrease).

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Question 32

Though almost half the candidates selected the correct answer **B**, many selected **D** as the answer. Rearranging the equation $P = V^2 / R$ leads to $V = (RP)^{½}$. The unit of potential difference could therefore be written as $(\Omega\,\mathrm{W})^{½}$.

Question 33

Most candidates found this question difficult, with many selecting **B** rather than the correct answer **A**, perhaps confusing **B** with the graph of current I against V for a filament lamp. As the potential difference (p.d) across the filament lamp is increased, the current in the lamp will also increase. The filament of the lamp will get hotter so its resistance will increase. Graphs **C** and **D** can be eliminated as these show the resistance either decreasing or remaining constant as the p.d. is increased. Graph **B** can be rejected as the filament will still have some resistance even when the p.d. across the lamp is very small.

Question 36

More candidates selected **B** rather than the correct answer **D**. In the parallel circuit given in the question, $V_1 = V_2 = V_3 + V_4$. Rearranging this equation gives $V_3 + V_4 - V_2 = 0$.

Question 38

Most candidates found this question difficult, with as many selecting **B** or **C** as the correct answer **D**. The circuit is one resistor (in the A_3 branch) in parallel with two identical resistors (in the A_1 branch) in parallel with three identical resistors (in the A_4 branch). The reading A_1 is 0.6 A, so reading A_3 is twice this (1.2 A) and reading A_4 is ⅓ of A_3 (0.4 A). As a check, the total current in the cell is 0.6 + 1.2 + 0.4 = 2.2 A.

Question 39

Fewer than half of the candidates answered this question correctly. When an α-particle is emitted from an unstable nucleus, the proton number decreases by 2. When a β^- particle is emitted, the proton number of the nucleus increases by 1. To produce a different isotope of the original unstable nucleus, the net change to the proton number must be zero – a minimum of one α-particle decay and two β^- particle decays.

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PHYSICS

Paper 9702/12
Multiple Choice

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

General comments

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

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

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

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Comments on specific questions

Question 6

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

Question 7

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

Question 8

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

Question 10

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

$$qE + kv_0 = mg$$

where k is a constant. Rearranging this equation:

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

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

Question 11

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

Question 16

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

Question 19

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

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Question 29

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

Question 34

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

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

Applying Kirchhoff's second law around the whole circuit:

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

Rearranging this equation gives the value of R, which is

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

Question 35

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

Question 37

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

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

This gives $R = 3.0\,\Omega$, which is answer **A**.

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PHYSICS

Paper 9702/13
Multiple Choice

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

General comments

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

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

Candidates found **Questions 10**, **11**, **13** and **36** difficult. They found **Questions 1**, **2**, **5**, **8**, **19**, **24** and **37** relatively straightforward.

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Comments on specific questions

Question 7

The majority of candidates selected the correct force **A**, but many others selected **B**, suggesting a misunderstanding of Newton's third law. Force **B** will be equal and opposite to the weight of the box (as the box is at rest) but this is not the force that forms a pair with the weight of the box in Newton's third law. The pair of forces referred to in Newton's third law are always of the same type and always act on different objects. In this example, both forces of the pair are gravitational – the pull of the Earth on the box (its weight) and the pull of the box on the Earth. The two forces act on different objects, the box and the Earth.

Question 9

Many candidates selected the correct answer **B**; most of the other candidates selected **C**. As the collision is perfectly elastic, the speed of separation of the two objects is equal to the speed of approach. Before the collision, object X approaches Y with a relative speed of $20 - 12 = 8\,\mathrm{m\,s^{-1}}$; after the collision Y must have a speed relative to X of $8\,\mathrm{m\,s^{-1}}$ and therefore an actual speed of $8 + 10 = 18\,\mathrm{m\,s^{-1}}$. Some candidates may have misinterpreted the speed of approach and speed of separation as simply the sums of the two speeds ($20 + 12 = 10 + 22$).

Question 10

The majority of candidates recognised (correctly) that the upthrust on the sphere does not change, but many thought that the resultant force on the sphere would increase.

When the sphere is released, the resultant force on the sphere is the upthrust U minus the weight W of the sphere, $U - W$. As the sphere rises it accelerates, increasing the viscous (drag) force D on the sphere. The resultant force on the sphere, $U - (W + D)$ must decrease (i.e. answer **B**).

Question 11

Some candidates selected **C** rather than the correct statement **A**. In force diagram Y there is a net force to the left of 20 N but the anticlockwise torque has a value of $20 \times 0.50 = 10\,\mathrm{N\,m}$.

Question 13

Many candidates found this question difficult. Most simply substituted the value for the density of air at sea level into the equation $p = \rho gh$ to find the height h of the atmosphere, ignoring the variation of the density of air with height above sea level. This gives a value for the height of the atmosphere of 7.8 km (answer **A**).

A simple way to approach this question is to consider the weight of a column of air of cross-sectional area A and height h stretching from sea level to the edge of the atmosphere. The density of the air decreases linearly with height above sea level, so the average density of air in the column is $\rho_0 / 2$ where ρ_0 is the density of air at sea level. The difference in pressure between the bottom and the top of the column of air is P_0, the atmospheric pressure at sea level. The weight of the air column is $\rho_0 gAh / 2$ and therefore $P_0 = \rho_0 gh / 2$, which can then be solved for ρ_0 to give answer **B**.

Question 25

The majority of candidates were able to recall that the intensity I of a wave is proportional to the square of the amplitude a, and hence $a \propto \sqrt{I} \propto 1 / r$ (answer **A**). Most of the other candidates assumed the intensity of a wave was directly proportional to the amplitude and selected **B**.

Question 29

Approximately half the candidates answered this question correctly. Many others selected either **B** or **D** in equal numbers. The curved lines can be considered to represent wave peaks at one instant. At **B**, two wave peaks are superposing, producing a wave peak with a larger amplitude; at **D**, two wave troughs are meeting, producing a wave trough with increased amplitude.

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Question 35

The box must contain a diode as this is the only component that behaves differently when a positive or negative potential difference is applied across it. If the diode is in parallel with the filament lamp, the ammeter would still record a large current in the circuit regardless of the sign of the potential difference across the box, so **C** cannot be the correct answer.

Question 36

Candidates found this question difficult, with many selecting **C** or **D** rather than the correct answer **A**. If the 10 Ω fixed resistor is replaced by a resistor of resistance 20 Ω, the current I in the resistor will fall. The power dissipated in the fixed resistor is I^2R when its resistance is R. The value of R has doubled but I has approximately halved, so the power dissipated in the fixed resistor must decrease (i.e. statement **C** is correct). The current in the internal resistance has also decreased, so the 'lost volts' Ir will also decrease and therefore the terminal p.d. will increase (i.e. statement **D** is correct).

Only statement **A** is incorrect. Statement **A** could have been correct for a cell with no internal resistance, but it is not correct for this cell.

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PHYSICS

Paper 9702/21
AS Level Structured Questions

Key messages

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

General comments

The marks awarded varied over a wide range. There were some high-scoring papers where candidates showed a good understanding of topics across the full range of the syllabus. There were also other candidates who had significant gaps in their basic knowledge.

A small minority of candidates left a significant number of their answer spaces blank. Candidates should always be encouraged to attempt all parts of all questions.

There were certain questions that most candidates found particularly challenging. These included knowing how to use two metal plates to produce a given uniform electric field in **Question 2(a)**, understanding an experiment to demonstrate two-source interference using water ripples in **Questions 5(a)** and **5(b)**, and interpreting the I–V characteristic of a semiconductor diode in **Question 6(b)**.

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

Comments on specific questions

Question 1

(a) (i) Most candidates successfully estimated the mass of a pencil. Candidates who were unsuccessful tended to overestimate its mass.

(ii) Most candidates found it difficult to recall the wavelength of ultraviolet radiation. Many either stated a value of wavelength that was too long or did not attempt a response.

(b) (i) The period of the oscillations was usually calculated correctly.

(ii) Stronger candidates found it relatively straightforward to calculate the percentage uncertainty, although a common error was to forget the need to divide by two because of the square root function in the given formula. Candidates who were able to calculate the correct percentage uncertainty often went on to calculate the correct value of absolute uncertainty. Very few realised that the absolute uncertainty should be expressed to one significant figure in the final answer.

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Question 2

(a) A precise description of how the plates should be used was needed. Candidates needed to describe the vertical orientation of the plates (and not just say that the plates are parallel). Candidates also needed to describe how the left plate was positively charged and the right plate was negatively charged; it was not sufficient only to say that the plates should be oppositely charged.

(b) Most candidates were able to correctly calculate the magnitude of the electric force. Some of the weaker candidates incorrectly assumed that the magnitude of the electric force would be equal to the magnitude of the weight of the bead.

(c) Candidates needed to use Pythagoras' theorem to show that the resultant force acting on the bead was 7.2×10^{-5} N. In 'show that' questions, credit is given for showing the calculation as well as the final answer. Candidates needed to carefully present each step of the calculation.

(d) Only the strongest candidates were able to explain that the resultant force on the bead is constant because the weight and the electric force are both constant as the bead moves along the path. Some candidates only referred to the electric field being uniform, which was insufficient.

(e) (i) Although there were many fully correct answers, a common mistake was to use just the weight or just the electric force, instead of the resultant force, to calculate the acceleration of the bead. The weakest candidates sometimes divided the resultant force by the weight instead of by the mass.

(ii) Successful candidates realised that they could calculate the answer by using an equation representing uniformly accelerated motion.

Question 3

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

The majority of the candidates were able to state the formula relating the density to the mass and the volume. Some candidates did not explicitly show how they obtained the value for the cross-sectional area of the cylinder in which the air moves, which was an important step in the overall calculation.

(b) (i) Those candidates who were able to recall the formula for the momentum of an object usually found it straightforward to apply that formula to the question.

(ii) This question was generally well answered. Some of the weaker candidates simply calculated a force that was equal to the weight of the air.

(c) (i) To answer this question, it was necessary to understand that the air exerts a force on the propeller that is equal in magnitude to the force that the propeller exerts on the air. The candidates who understood this were immediately able to state the correct numerical answer.

(ii) Most candidates could state the name of the law. A small number of candidates referred vaguely to 'Newton's law of motion' rather than Newton's third law of motion.

(d) Only a minority of the candidates understood that, when the aircraft is hovering, the weight of the aircraft is equal to the total upward force on the propellers. A significant proportion did not give a response to this part of the question.

(e) The stronger candidates correctly identified the reason as being the lower density of air at high altitude. Some candidates gave vague or imprecise answers such as 'thinner air' or 'less air' at high altitude. A common misconception was that the aircraft needed to have a greater upward force on it because there is a greater magnitude of gravitational force at high altitude.

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(f) Most candidates attempted to use the Doppler effect symbol equation given on the Formulae sheet. A common error was to substitute the speed of the aircraft with the wrong sign into the equation.

Question 4

(a) This question was generally well answered.

(b) Many candidates could recall a correct formula for elastic potential energy, but most had difficulty applying it to the question. Some of the weaker candidates confused elastic potential energy with gravitational potential energy.

(c) Most candidates could recall and apply the correct formula for gravitational potential energy.

(d) (i) A common error was to attempt to calculate the kinetic energy by adding the gravitational potential energy to the elastic potential energy instead of subtracting the gravitational potential energy from the elastic potential energy.

(ii) Most candidates were able to quote the standard formula for kinetic energy and then use this to determine the speed of the block.

Question 5

(a) (i) Some candidates stated that the waves should have a constant phase difference. This does not answer the question because it does not describe how the apparatus is arranged to ensure that the waves are coherent. Only the strongest candidates were able to correctly describe how the dippers should be connected to the same vibrator/motor.

(ii) Only a small proportion of the candidates realised that the waves need to have a similar amplitude when they overlap in order for the interference pattern to be observable.

(b) It was expected that the candidates would refer to a means of 'freezing' the pattern such as by using a stroboscope. Some candidates suggested using a suitable video camera. Others described doing the experiment in a darkened room to remove unwanted ambient light.

(c) Most candidates were able to calculate the period of the waves from their frequency and speed.

(d) (i) Candidates who were unable to calculate the correct path difference sometimes guessed a random incorrect value. A common incorrect value was 0.5 cm, possibly due to these candidates thinking of the path difference in terms of wavelength.

(ii) Many candidates were able to state the correct phase difference of 180°. The most common incorrect answer was 0.

(e) The most common correct answer was a straight line joining points that are equidistant from the two dippers.

Question 6

(a) Many candidates attempted to explain potential difference, but did not give a correct definition. For example, 'the energy transferred when unit charge passes between two points' has omitted the idea of a ratio. Candidates should ensure that they refer to unit charge and not one coulomb. It is always essential to use precise wording when giving the definition of a quantity. Some candidates said that it was 'current multiplied by resistance'. This is a way of calculating potential difference but does not define it.

(b) Most candidates found this part of the question to be challenging. A common mistake was to describe the resistance as being initially zero and then increasing. The weaker candidates sometimes described how the current varied with potential difference, but without making any reference to the resistance.

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(c) (i) It was necessary to convert the unit of current from mA to A in order to avoid having a power-of-ten error in the calculated resistance. Some candidates made the incorrect assumption that the resistance would be equal to the reciprocal of the gradient of the graph. This only applies if the graph is a straight line through the origin.

(ii) 1. Different methods of calculation were possible. The most common method was to first calculate the total circuit resistance by dividing the terminal potential difference of the cell by the current in the cell. The resistance of X could then be found by subtracting the resistances of Y and the diode from the total circuit resistance.

2. Most candidates knew the relevant symbol formulae for power, although they tended to find it more difficult to apply these formulae to the question.

Question 7

(a) (i) Although there were many correct answers, a significant number of candidates incorrectly assumed that β^+ emission from a nucleus will increase its proton number by 1 instead of decreasing it by 1. A small number of candidates confused the nucleon number with the number of neutrons.

(ii) The most common answer was the correct one. A significant minority of candidates incorrectly named Y as an electron or a gamma-ray.

(b) Although many candidates were able to recall the charge of a down quark, the charge of a strange quark was less well known.

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PHYSICS

Paper 9702/22
AS Level Structured Questions

Key messages

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

General comments

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

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

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

Comments on specific questions

Question 1

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

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

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

Question 2

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

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

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(ii) This question was generally well answered.

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

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

Question 3

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

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

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

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

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

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

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

Question 4

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

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

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

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

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

Question 5

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

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

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

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

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

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

Question 6

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

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

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

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

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

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

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

Question 7

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

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

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PHYSICS

Paper 9702/23
AS Level Structured Questions

Key messages

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

General comments

The majority of the candidates seemed to have had time to finish the paper to the best of their ability. There were a few parts that most candidates found particularly challenging. These included the last part of the question on moments (**Question 1(b)(ii)**) and the last part of **Question 6(d)**, on an electrical circuit.

Comments on specific questions

Question 1

(a) The majority of the candidates gave the correct base units for the moment of a force. A significant number misread the question and gave the base units for force. A small minority included the newton as a base unit.

(b) (i) The were a considerable number of correct responses. Some of the answers were given with a power-of-ten error due to the not converting the lengths from centimetres into metres. The weaker candidates were unable to calculate the perpendicular distance of the line of action of the weight from the pivot P.

(ii) The majority of the candidates gave the general condition for equilibrium but did not apply the condition to the actual situation in the question. Very few candidates explained that the distance of the line of action of the weight from the pivot needed to be zero for there to be no resultant moment caused by the weight. There were many answers that just repeated the question, describing the position of the centre of gravity, or that just explained what is meant by the centre of gravity. Very few candidates mentioned the presence of the weight and its effect on the equilibrium position.

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Question 2

(a) There were many correct statements of what is meant by work done. A significant number of candidates did not give the required description in full. A large number simply stated 'force multiplied by distance', which is not sufficient at this level.

(b) (i) 1. The majority of candidates determined the acceleration. A considerable number used the gradient of the graph and many others used values of velocity and time from a point on the graph.

2. The candidates had to calculate the distance moved by the lift from the area under the graph and use the correct force applied to move the lift. The majority calculated the correct distance but a considerable number used an incorrect force. Some candidates omitted the frictional force from the total force needed. Others subtracted the frictional force from the weight or just used the frictional force.

(ii) The majority of the candidates were aware of the equation $P = Fv$ and obtained the correct velocity from the graph. A significant number of candidates used an incorrect tension to calculate the power output. Many tried to use the various forces given in the question in different combinations. The power required was at a specific time. The tension given and the velocity of the lift at this time were expected to be used to calculate the output power of the motor. The efficiency of the motor was then used to determine the input power. There were many who used the given efficiency incorrectly and some obtained an input power that was less than the output power.

(iii) There was a range of answers given for this question. Some incorrectly suggested that there was more potential energy gained than work done by the motor. Many answers were not given in sufficient detail.

Question 3

(a) (i) A large number of candidates gave the correct response. A significant number of the weakest candidates gave the name of a force such as weight or the name of an object such as a ball.

(ii) A large number of candidates gave the correct response. A significant number again showed a degree of confusion as to what was required.

(b) (i) The majority of the candidates were able to calculate the electric field strength. A significant number completed the question and determined the electric force on the charged particle in the electric field. There were a small number of candidates who used only half the separation of the plates when calculating the electric field strength. Some did not convert the separation from centimetres to metres. A few of the weaker candidates gave the value of the electric field strength as the answer for the electric force acting on the particle.

(ii) A minority of candidates were able to calculate the resultant force acting on the charged particle and then go on to calculate its acceleration. A small number of candidates calculated the accelerations that would be caused by the weight and the electric force acting separately. These candidates then calculated the overall acceleration. However, the question asked for the calculation to be determined using the resultant vertical force and so these candidates had not answered the question correctly. A significant number of candidates were unable to make any progress and often were able to obtain credit only for the inclusion of $F = ma$ somewhere in the working.

(iii) 1. Stronger candidates answered this part using the data for the vertical direction only. They applied the equations of motion for constant acceleration which were valid in the vertical direction. There were many candidates obtaining incorrect answers because they produced equations that mixed the horizontal velocity with the vertical acceleration. These candidates used an initial velocity of $0.75\,\mathrm{m\,s^{-1}}$ instead of zero. A large number of candidates gave their final answer to only one significant figure.

2. The majority of the candidates obtained the correct answer by using the equation *distance* = *speed* × *time*. There were a minority of candidates that used inappropriate equations of constant acceleration for the distance travelled in the horizontal direction.

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Question 4

(a) (i) The majority of the candidates gave the correct general expression for momentum. A significant number then resolved the velocity correctly and gave the required component of momentum. A small number gave the wrong component by resolving the velocity in the direction perpendicular to that required. The majority of the candidates gave the answer to the required three significant figures, although some gave the answer to three decimal places.

(ii) The majority of the candidates realised that the resultant momentum in the direction perpendicular to the line AB was zero. These candidates equated the two components of the momentum in this direction to obtain the correct answer. A small number equated the two momenta rather than the perpendicular components of momentum. A significant number gave their answer to one significant figure instead of the required three significant figures.

(iii) Only the strongest candidates were able to give the full analysis required of the momentum components before and after the collision. The full detail of each momentum component was required in this 'show that' question and many candidates needed to improve the presentation of their answers.

(b) (i) The majority of candidates completed the calculation correctly. There were very few errors in the calculation of the kinetic energy. A small minority were unable to complete the solution by equating the kinetic energy lost with the elastic potential energy gained.

(ii) 1. Very few candidates gave the correct graph. A small minority started with zero acceleration for zero compression. The compression increases in proportion with the force and therefore the acceleration over the region where Hooke's law is obeyed. This relationship was not shown by the majority of candidates. The majority drew curves of various shapes or a line with a negative gradient.

2. Only stronger candidates were able to give the correct graph. Many weaker candidates started with zero kinetic energy instead of a positive value. The graphs drawn indicated that the candidates had not properly considered how the velocity would change as the balls compressed the spring and came to rest.

Question 5

(a) (i) Many candidates gave the correct answer. There were some answers that were not accepted that suggested the condition was the same phase or the same frequency. These are not sufficient on their own.

(ii) Stronger candidates were able to give an acceptable description of interference. The majority did not describe waves overlapping to give a resultant displacement that was the sum of the individual displacements of the overlapping waves. Some candidates described the addition of amplitudes which indicates a misunderstanding of interference.

(b) (i) The majority of candidates gave the correct diffraction grating equation $n\lambda = d \sin\theta$. Some candidates were unable to calculate the slit spacing from the number of lines per unit length given in the question. Others used an incorrect value for n or θ.

(ii) The question asked for an explanation of the effect of changing the wavelength. This explanation was sometimes omitted or incorrect.

Question 6

(a) (i) The majority of the candidates applied the correct equation to calculate the resistance of a lamp. A significant number incorrectly calculated the resistance of both lamps by using the full potential difference provided by the battery as the potential difference across one lamp.

(ii) A significant number of the candidates realised that the current through the two resistors was the difference between the current in the battery and the current in the lamps, and calculating the total resistance for the resistor branch of the circuit led these candidates to the resistance R. A

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significant number of candidates used the wrong current or gave the total resistance of the resistor branch as their final answer.

(b) Stronger candidates were able to calculate the potential difference across the components of the two branches of the parallel arrangement. Many weaker candidates were unable to determine the difference in potential across one component in each branch to give the potential difference between X and Y.

(c) The majority of the candidates were able to give a formula for electrical power. There were many candidates who used the resistance of only one lamp or the incorrect potential difference across the lamps. A significant number used an incorrect value of the current in the battery.

(d) Candidates found it difficult to explain the changes to the different currents and hence to the power in the lamps or battery. The majority realised that the decrease in the resistance *R* would cause an increase in the current through resistance *R*. Many of these candidates then incorrectly concluded that there would be a reduction in the current through the lamps. These candidates did not realise that the potential difference across the lamps does not change and therefore the current through the lamps does not change.

Question 7

(a) The majority of the candidates were able to give at least one of the correct values.

(b) Stronger candidates could explain the difference in the kinetic energy of the α-particle and the energy produced in the decay process. Many others suggested that the energy transferred to other energy forms such as heat. Those that referred to the energy gained by the neptunium nucleus often did not describe this as kinetic energy.

(c) (i) Many candidates used an equation for the current such as $I = Nq / t$ without any value of charge for q, or used the charge of one electron for the charge of the α-particle.

(ii) Many candidates attempted to use an equation for power that was only appropriate for electrical components and was not applicable in this situation. A small minority used the equation *power* = *energy* / *time* and converted the energy given in eV to J for the decay of each nucleus of X. A significant number of candidates did not use the number of nuclei of X decaying in the time of 30 s.

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PHYSICS

Paper 9702/31
Advanced Practical Skills 1

Key messages

- Candidates should be encouraged to set up their graphs to make them easy to work with in later parts of the question, and to check that the scales used are linear. Candidates should be encouraged to use the whole graph grid available.

- Candidates need to use a sharp pencil to plot points and draw lines of best fit. Points should be drawn as neat crosses and not as 'blobs' (circles greater than half a square in diameter), and lines should be continuous, thin and straight. A transparent 30 cm ruler should be used for drawing lines of best fit.

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

General comments

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

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

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

Comments on specific questions

Question 1

(a) Most candidates stated V in range and with an appropriate unit. Some candidates omitted the unit.

(b) Most candidates stated a value for d in range and with a unit. Some candidates omitted a unit for d.

(c) Many candidates were able to collect six sets of values of R and d without assistance from the Supervisor. Some candidates collected more results. Few candidates collected five or fewer.

Many candidates did not reduce their R value to include $12\,\Omega$ or extend their value to include $39\,\Omega$. Candidates should be encouraged to make use of the whole range of resistors provided.

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Many candidates were awarded credit for the column headings. A few candidates omitted either the unit or the separating mark between the quantity and unit for one or more of the columns. The most common column heading omitted was that for R / d (unit $\Omega\,m^{-1}$).

Many candidates correctly recorded their raw values for *d* to the nearest 0.1 cm. Some candidates stated their measurement to the nearest cm. The ruler to measure *d* can be read to the nearest mm, so the number of decimal places in *d* must be consistent down the column.

The table work was done well by candidates. The mark for the range was the most difficult mark to obtain.

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

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

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

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

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

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

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

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

(e) Most candidates recognised that *A* was equal to the gradient and *B* was equal to the intercept calculated in **(d)(iii)**. Some candidates recorded a value with either no units or incorrect units.

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Question 2

(a) (i) Most candidates measured values of x in range and to the nearest mm. Some candidates stated the measurement to the nearest cm or 0.1 mm. This did not gain credit as the metre rule could be read to 1 mm.

(ii) Many candidates are familiar with the equation for calculating percentage uncertainty and gave an uncertainty in x that was appropriate for this experiment given the inherent difficulties in taking the measurements. Some candidates made too small an estimate of the absolute uncertainty in the value of x, typically 1 mm (from the precision of the measuring instrument) or too large an estimate, typically 0.5 cm.

Some candidates repeated their readings and correctly gave the uncertainty in x as half the range, although other candidates did not halve the range or did not show clearly that this is how they obtained their percentage uncertainty.

(b) (i) Most candidates stated their raw value of L to the nearest mm and in range. Some candidates stated the measurement to the nearest cm.

(ii) Many candidates correctly calculated $\sqrt{L}$. Some candidates truncated their answer instead of rounding correctly.

(iii) Many candidates correctly justified the number of significant figures they had given for the value of $\sqrt{L}$ with reference to the number of significant figures used in L only. Some candidates gave reference to just 'raw readings' or 'values in calculation' without stating what these values were, or mistakenly related their justification to other quantities, e.g. x.

(c) Most candidates recorded second values of x and L. Candidates who carried out the experiment carefully measured a second value of L (for the larger x) to be greater than their first L value.

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

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

(e) (i) Many candidates stated values of T in range.

(ii) Some candidates calculated g correctly stating a correct unit. Many candidates omitted units or gave incorrect units, stating $\mathrm{m\,s^{-2}}$ when in fact cm was used in the calculation without conversion into m.

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

Various reasons for difficulty in measuring x, L_0 or L were given, such as having to hold the ruler in mid-air or there was parallax error in these measurements. Also commonly seen were limitations relating to the difficulty in judging when the two pendulums were exactly in phase. To gain credit, the quantity that was difficult to measure should be specified along with the difficulty. Just 'parallax error', 'parallax error while reading values' or 'difficult to measure x or L' were not specific enough to be given credit.

Credit is not given for suggested improvements that could be carried out in the original experiment, such as 'repeat measurements', 'do more readings to get an average value', 'look perpendicularly

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onto the ruler', etc. Unrealistic solutions were also not given credit, e.g. 'robotic arm' or 'mechanical hand' to hold and release the pendulum. In this particular experiment, attention to an improvement (e.g. clamping the ruler to measure x or L) was more important than providing a method to eliminate any forces on release. Problems that were irrelevant or that could have been removed if the candidate had taken greater care were not given credit. Vague or generic answers such as 'too few readings' (without stating a consequence), 'faulty apparatus' or 'use an assistant' were also not given credit.

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

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PHYSICS

Paper 9702/33
Advanced Practical Skills 1

Key messages

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

General comments

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

Comments on specific questions

Question 1

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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Question 2

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

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

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

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

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

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

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

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

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

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

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

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

Various reasons for difficulty in measuring x were given, such as having to hold the ruler vertically in mid-air or there was parallax error in these measurements. Also commonly seen were limitations relating to the difficulty in aligning the magnets vertically so that the oscillations were in the vertical plane only. To gain credit, the quantity that was difficult to measure should be specified along with the difficulty. Just 'parallax error', 'parallax error while reading values', 'hard to measure distance between the two magnets' or 'difficult to measure x' without further detail cannot be awarded credit. Another reasonable problem was that the values of the $T_2 - T_1$ were short (or

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there was a large percentage uncertainty in the $T_2 - T_1$ value). There was no credit for stating that the times themselves were too short.

Credit is not given for suggested improvements that could be carried out in the original experiment, such as 'repeat measurements', 'do more readings to get an average value', 'look perpendicularly onto the ruler', etc. Unrealistic solutions were also not given credit, e.g. 'robotic arm' or 'mechanical hand' to hold and release the magnet. In this particular experiment, attention to an improvement in measuring *x* (e.g. clamping the ruler) was more important than providing a method to eliminate any forces. Problems that were irrelevant or that could have been removed if the candidate had taken greater care were not given credit.

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

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PHYSICS

Paper 9702/34
Advanced Practical Skills 2

Key messages

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

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

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

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

General comments

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

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

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

Comments on specific questions

Question 1

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

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

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

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

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

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

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

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

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

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

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

Most candidates plotted their points on the graph paper carefully; others needed to draw the plotted points so that the diameters of the points were equal to, or less than, half a small square (a small but clear pencil cross, or a point with a circle, is recommended).

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

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

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

Candidates need to check that the triangle for calculating the gradient is large enough (the hypotenuse should be greater than half the length of the line drawn).

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

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

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

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

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

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

Question 2

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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PHYSICS

Paper 9702/35
Advanced Practical Skills 1

Key messages

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

General comments

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

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

Both questions were attempted by most candidates and there did not seem to be a shortage of time in most cases. Good practical skills were demonstrated in the generation and handling of data but candidates could improve by giving more thought to the analysis and evaluation of experiments.

Comments on specific questions

Question 1

(a) Stronger candidates understand the meaning of 'period of an oscillation' T and the experimental technique of measuring the time of several oscillations N then dividing by N in order to measure the period. They correctly record the raw time for several oscillations e.g. 10 or 5, repeating their timing once or twice. The average time was calculated before correctly dividing by N to find T. Weaker candidates recorded only one time with no repeat measurements, did repeats but then did not divide by the number of oscillations, or recorded repeated times for a single oscillation rather than N oscillations. Some candidates found frequency rather than period.

A unit was not given on the answer line, so for full credit candidates needed to provide the unit.

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(b) Stronger candidates recorded six sets of readings and included the number of clips n, raw values of time, number of oscillations used, periodic times T and T^2 in neatly presented tables. A number of tables in weaker answers did not record raw times.

Better answers showed a large variation in n values, i.e. candidates had used the largest n value and the smallest n value that could be achieved with the apparatus. Weaker answers showed too small a variation in n; commonly 3 to 13 or 4 to 9.

Some weaker candidates omitted units in the column headings or did not include a separating mark between the quantity and its unit e.g. T^2 s^2, or gave the wrong unit e.g. T^2 / s.

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

Successful treatment of significant figures was shown when calculated values for T^2 were recorded to an appropriate number of significant figures from raw data, i.e. to the same number as (or one more than) the number of significant figures in the raw time values given in the table.

Many candidates calculated T^2 correctly. Weaker answers had errors in calculations often caused by incorrect rounding of the final value by truncating rather than rounding. Candidates should be encouraged to record raw values of the time for N oscillations in their tables, and not just the values of calculated period.

(c) (i) Stronger candidates used axes for their graphs that were labelled with the appropriate quantities i.e. T^2 and n. Weaker candidates often omitted the labels or wrote the unit of the quantity e.g. s^2 rather than the label T^2.

It is important that candidates select sensible scales. Better answers used a scale which was easy to interpret e.g. on the T^2 axis 10 small squares were equal to 0.1 giving the value of one small square equal to 0.01; on the n axis 10 small squares were equal to 2 so one small square was equal to 0.2. Weaker answers used, for example, on the n axis 15 small squares equal to 2, so one small square with this scale was equal to 0.1333. Such scales are very difficult to work with and can cause the candidate to make mistakes with read-off values in several different places.

Some candidates used non-linear scales with values missing, e.g. 1.9, 2.0, 2.2 (where 2.1 is missing). Some had scales where the last value was 'squashed' to fit all the points on the grid by changing the scale, e.g. 2.4, 2.5, 2.7. These types of scales cannot gain credit.

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

Candidates should take care to plot points to an accuracy of at least half a small square in both the x and y directions. Weaker candidates often use thick pencil tips and produce points larger than half a small square. Many graphs could be improved by the use of a sharp pencil to draw fine points so that the points have a diameter less than half a small square.

Successful candidates who took measurements carefully produced good quality points with all points lying within ± 1 (to scale) on the n axis. Weaker candidates often placed a point far from the others as the point was mis-plotted. When a point appears to be well away from the trend of the other points, candidates should check they have placed the point in the correct position. If the point is found to be plotted correctly then candidates should go back, check their table values and consider retaking the times as the stop-watch may have been misread.

(ii) Stronger candidates showed carefully considered lines of best fit, but weaker candidates often joined the first and last points on the graph regardless of the distribution of the other points. There should always be a balanced distribution of points either side of the line along the entire length. Many lines needed rotation to get a better fit, or an anomalous point needed to be identified to justify the line drawn. Some candidates were not awarded credit because their lines were kinked in the middle, a double line or drawn freehand without the aid of a ruler.

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(iii) Successful candidates clearly showed how to find the gradient and intercept of a straight-line graph. These answers had a gradient value that matched the gradient of the graph i.e. a graph with a negative gradient was written with a minus sign in front of the value. Weaker answers omitted the minus sign.

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

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

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

(d) Candidates needed to make a direct transfer of their values from **(c)(iii)** to **(d)**. In this question no additional calculations were necessary. Some weaker candidates recorded fractions for P or Q or showed fresh substitutions into the equation and further calculations.

Weaker candidates omitted the units s^2 or gave wrong units.

(e) Stronger candidates interpreted the question correctly and drew a line labelled W which was parallel to and higher up the graph paper than the candidate's line. Weaker candidates often drew a line W which crossed over their original line or omitted line W.

Question 2

(a) (i) Most candidates slowly and carefully raised the board until the magnet started to move, producing a value of α less than 90°. Good answers showed raw values of α to the nearest degree. Weaker answers had raw values of α to 0.1°.

Stronger candidates recognised that α was a difficult measurement to take and repeated their measurement, noting several values of raw α. The problem of keeping the board in the exact position at which the magnet started to move could be stated as a limitation in **(g)**.

(ii) Successful candidates showed the working used to calculate the percentage uncertainty in α. The value of absolute uncertainty $\Delta\alpha$ was clearly stated as between 2° and 5° or $\Delta\alpha$ was calculated using half the range of repeated α measurements. Some weaker candidates used the whole range for $\Delta\alpha$ or did not multiply by 100 when finding the percentage.

(b) Successful candidates used the rule to measure x to the nearest mm. Weaker candidates gave raw values to 0.1 mm.

As the block could be placed directly on the rule and the candidate's head placed directly overhead, stronger candidates recognised that there was no difficulty in taking this measurement. Weaker candidates thought this measurement could be used as a source of limitation in **(g)**.

(c) Most candidates correctly placed the magnets attracting each other and fixed the block on the board, so that when the board was raised the angle measured for β was greater than α. Some weaker candidates measured β that was less than α.

(d) (i) Successful candidates recorded a value for y and correctly calculated a value for $(x + y)^2$ where x and y had the same unit.

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(ii) Candidates needed to be specific and relate the number of significant figures in the value of $(x + y)^2$ ideally to the number of significant figures in their value of $(x + y)$, or to their values of x and y. Successful answers referred specifically to $(x + y)$ or to the significant figures in x and y (i.e. the relevant quantities in this question). Weaker answers included statements such as 'raw data', 'values in the calculation', x on its own, the precision of the ruler, decimal places, or gave a bald statement such as '3 significant figures'.

(e) Most candidates showed that the block had been turned around and second values of x and β were recorded. With the larger value of x, the second value of β should be less than the first value of β but β should still be greater than α. Weaker answers had values did not follow the correct pattern.

(f) (i) Stronger candidates used a correct rearrangement of the equation and calculated k for both experiments. If answers showed measurements that had been retaken producing new values, candidates should use the latest measurements and take them through into the calculation of k. Weaker candidates rounded in the middle of the calculations producing inaccurate values, or did not take the latest measurements through into the calculation of k.

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

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

(g) **Question 2** is designed to have flaws and to present challenges when candidates take measurements. Often there is other apparatus that could be used to ensure more accurate readings. Successful answers suggested four different limitations discovered while experimenting in **(g)(i)**, and then continued in **(g)(ii)** with valid methods or suggestions for other apparatus that could be used to address these limitations.

Stronger candidates stated 'only two distances of x were used to test the relationship, and this is not enough to draw a conclusion'. Weaker answers just stated 'two readings are not enough' or 'two sets of readings are not enough to take accurate readings' or 'two sets of readings are not enough to conclude the experiment'. Some successful candidates went beyond the suggestion of 'take more readings' and correctly suggested taking more readings and plotting a graph.

Stronger candidates gave a valid reason for difficulty in measuring the angles, e.g. it was difficult to hold the board and the protractor at the same time, or the board moved as it was held by hand during the angle measurement. Weaker answers simply stated that it was 'difficult to measure the angle' without giving a reason. Successful suggestions for improvement to the angle measurement were to 'clamp the board or the protractor' or 'to video/film/record the board with the protractor in view'.

Some candidates suggested that aligning the magnets was a difficulty, but this was not an issue as the adhesive putty was malleable enough that the magnets could be placed in good alignment.

It was difficult to stop the board at the exact angle at which the magnet started to move, and there were valid methods to raise the board in small increments. Weaker answers suggested 'use a pulley' or 'a mechanical method to raise the board' but these answers were too vague.

Another issue which featured in stronger answers was the problem with the base of the board sliding along the bench as the top end was raised. Candidates needed to identify a specific solution, and an answer such as 'placing something' at the bottom of the board was insufficient.

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Some candidates identified that the variation of friction over the whole board could be an issue, and suggested solving the problem by sanding the board, but credit could not be given for ‘smoothing’ the board unless the method was specific.

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.

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Paper 9702/36
Advanced Practical Skills 2

Key messages

- Copying out a table of readings can result in transcription errors, so it is good practice to plan and prepare a table before taking measurements. The table should include columns for any calculated values. Measurements can be recorded in the table as they are taken, and it is not essential that the values are in numerical order. Any values that are not used in further analysis and graphs should be neatly crossed out.
- It is important that a wide range of values is included when taking a series of readings. The maximum range is defined by the physical limits of one or other of the parameters being measured, and the maximum and minimum measurements should be reasonably near to these limits.
- To be successful answering **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out and relate in turn to the measurements taken. To practise and develop this skill, candidates should be encouraged to look at the experiment chronologically stating the limitations as they encounter them or focus on the difficulties of the measurements that they are asked to collect.

General comments

There was no evidence that centres had any difficulties in providing the equipment specified for use by the candidates.

The Supervisor's Reports from many centres included useful detail about the apparatus and about difficulties encountered in the experiments and any help provided. Such detail is useful to the Examiners who can take it into account when marking the candidates' work. For example, some centres reported that the large voltage steps in their power supplies made it difficult to obtain the specified current, so the Examiners could ensure that their candidates were not disadvantaged.

For many centres the candidates' work was of a good standard, with data and graphs presented clearly. The final descriptive analysis proved to be the most difficult section. There did not seem to be a shortage of time and all sections of the two questions were answered by almost all the candidates.

Comments on specific questions

Question 1

(a) (i) Candidates were asked to make a cylinder approximately 20 cm long, and most recorded an initial measured length close to this.

(ii) Most candidates recorded the balance distance *L* to the nearest millimetre.

(b) After reducing the length of the cylinder, nearly all candidates recorded an increased *L* value.

(c) Many candidates gave well-presented tables containing six values of *x*.

In some cases the *x* values increased rather than decreased down the table, indicating that the original recordings had been copied out in the new sequence. Candidates could still be awarded

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credit for this, but it was unnecessary. Candidates should be advised that unnecessary copying out can result in transcription errors.

In many cases the candidates did not choose to use a wide enough range of values, and did not include any small values for x.

A small number of candidates omitted the unit for x^2 in their table headings. Some others gave it as cm instead of cm^2.

Most candidates recorded their x and L values to the nearest millimetre. In a few cases candidates could not be awarded credit because all the L values appeared to have been measured to the nearest centimetre.

There were very few mistakes in the number of significant figures given in the calculated x^2 values. Weaker candidates sometimes gave too many significant figures, e.g. for $x = 15.9$ cm, x^2 was recorded as 252.81 cm^2 instead of 252.8 or 253.

(d) (i) There were many very good graphs. In a few cases the candidate had plotted data from the wrong column in their table, producing a graph of x against x^2.

In most cases the axis scales were easy to use, with straightforward grid-to-value ratios (such as 10 small squares representing 50 cm^2), and the scales made good use of the grid area. Good graphs had axis markings at simple intervals.

Most candidates plotted their points neatly using small crosses. Candidates should be discouraged from using very large dots because the accuracy cannot be judged if large dots are used.

The quality of the data was judged by the linearity of the points, and for most candidates the amount of scatter was reasonable.

(ii) Stronger candidates fitted a straight line to the plotted points well, with a balance of points on either side along the entire length. One point could be ignored in drawing the line of best fit if it was labelled as anomalous.

(iii) Nearly all candidates knew how to find the gradient of their line and showed their working clearly. Various techniques were used by different candidates, but all needed to use the coordinates of two points on the line. In most cases the two points were well separated (by at least half the line length).

The gradient value needed to be presented with a minus sign if the graph had a negative trend.

In a few cases the intercept was mistakenly read directly from the L-axis where there was a false origin (i.e. the x^2 axis did not start from zero).

(e) Most candidates recognised that a was equal to the value of the gradient and b was equal to the intercept. Some candidates could not be given credit because one of these values was presented as a fraction or had only one significant figure.

A large number of candidates included correct units for both a and b values.

Question 2

(a) The measurement of the initial height h_0 was straightforward. A small number of candidates unrealistically recorded their value to the nearest 0.1 mm.

(b) (i) When the circuit was switched on, the candidates in some centres could not set the current in the wire in the specified range owing to the large voltage steps in their power supply. The Examiners allowed values outside the stated range so these candidates were not disadvantaged.

The heated wire had a resistance of approximately 5 Ω so a value of V of approximately 2 V was expected. A few candidates recorded a value for V of less than 0.1 V, so it is likely that they had connected their voltmeter across the ammeter instead of the wire.

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(ii) Nearly all candidates recorded a value for h for the heated wire which was less than h_0, as expected.

(iii) The simple calculation of the change in h was nearly always correct.

(c) The more able candidates successfully estimated the percentage uncertainty in Δh, giving a value as high as 50% or even 100%. Some weaker candidates incorrectly added the percentage uncertainties of h and h_0.

(d) Examiners were looking for a correctly calculated value for T given to the nearest K, and most candidates were able to do this.

Values to greater precision were not accepted since Δh had only one significant figure, so $\alpha\Delta h$ could not reasonably have more than two significant figures. For example, if Δh is 4 mm then $\alpha\Delta h$ is 47 K, so T has to be to the nearest K.

(e) Nearly all candidates were credited for a second set of readings and for the correct trend in Δh.

(f) (i) The calculation of β values was generally carried out very well.

(ii) Many candidates correctly argued that the significant figures in β depended on the significant figures in I, V and $T^4 - T_0^4$. Vague arguments involving reference to just 'raw data' were not accepted.

(iii) There were many very good answers to this question. Stronger candidates looked at the variation between the two β values (usually by calculating the percentage difference) and then compared it with what they considered as allowable for this experiment (e.g. 20%).

(g) In general, this was found to be the hardest section of the question paper. Weaker candidates tended to describe errors and apparatus difficulties without making a link to a particular measurement.

Many candidates are familiar with the idea that two sets of results are not enough to draw a confident conclusion, and that more test data could be analysed using a graph.

The most important difficulty specific to this experiment is the large percentage uncertainty in Δh because it is a very small quantity that is derived from imprecise measurements made with a metre rule with only millimetre divisions. Some candidates did identify this, but few went on to suggest an improvement based either on making Δh larger (by increasing the current or making the wooden strip longer) and/or specifying more precise measuring equipment.

Many candidates were concerned that the metre rule might not be vertical but not all mentioned which measurement could be affected by this problem.

Difficulty caused by fluctuating ammeter and voltmeter readings was often identified as a problem, and some candidates described a method of cleaning electrical contacts to reduce this.

Many candidates pointed out that the room temperature T_0 might vary from the stated value provided, and some went on to suggest using a thermometer to measure T_0 at the time h was being measured.

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.

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Paper 9702/41
A Level Structured Questions

Key messages

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

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

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

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

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

General comments

There was a wide spread in the standard of candidates, with marks awarded across the full mark range. Candidates managed their time well with little evidence of candidates not being able to complete the paper.

There were many answers where candidates attempted to write all that they knew rather than focusing on answering the question. This should be discouraged as it not a good way of approaching the paper.

Working for calculations was nearly always shown, which is encouraging, and use of English was very good in general.

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Comments on specific questions

Question 1

(a) Although well answered by many candidates, the most common omission was the fact that the masses involved are point masses.

(b) (i) Many candidates were able to state features of the orbit of a geostationary satellite. Some weaker candidates repeated ideas already within the question and some just rephrased what geostationary means, i.e. above the same point on the Earth at all times.

(ii) Many candidates did not meet the requirement to explain their working here. They need to begin with a fundamental principle they are applying, which here is that the gravitational force provides the centripetal force. The calculation was generally correct, but there were errors in forgetting to square the time period or cube the radius. Power-of-ten errors were also evident due to forgetting to convert the radius from km into m. A small but significant number of candidates started with the incorrect assumption that the gravitational field strength at the satellite would be $9.81\,N\,kg^{-1}$.

Question 2

(a) In general, most candidates received at least partial credit here. Candidates needed to be clear in their answers whether they were referring to the volume of one molecule or the volume of all of the molecules.

(b) (i) There were two approaches to this calculation. The first one, using $pV = NkT$, is more straightforward, but was used by a small number of candidates. A second approach, $pV = nRT$, involves a further step to go from the number of moles n to the number of molecules N. A common error was to confuse these two and to stop at 4.5. Candidates should realise that 4.5 cannot be a realistic answer for the number of molecules in a container of gas. Almost all candidates remembered to convert the temperature from Celsius into kelvin.

(ii) This was an estimation question. Some candidates gave their estimates to 3 significant figures, which was inappropriate given the precision of the data.

(c) In order to refer to their answer in **(b)(ii)**, candidates needed to include their numerical value and then compare this to the numerical value of the volume given. Simply saying that one was larger than the other was not sufficient as it does not justify the assumption.

Question 3

(a) Candidates knew that change of state occurs at constant temperature. Many candidates did not make clear that specific latent heat is the amount of energy per unit mass for this to happen. The amount of energy to change the state of 1 kg does not make it clear that division by mass is involved in the definition.

(b) (i) Most candidates were able to interpret the graph to determine the mass of liquid evaporated.

(ii) Candidates found it difficult to demonstrate the knowledge that rate of loss of thermal energy depends on the difference in temperature between the body and its surroundings. Here, with different power ratings, the temperature of the liquid was the same both times.

(iii) Candidates found this calculation challenging and many did not include the heat losses in their calculations. Other errors were not converting from minutes into seconds, using the wrong time interval such as 12 minutes and also using the incorrect change in mass.

(iv) This calculation was also challenging. Many candidates found the average of the two input powers or the difference between them.

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Question 4

(a) (i) Most candidates gave the idea that this was the distance from the central equilibrium position. Only a small number of candidates went on to say that the direction was needed as well. Some candidates used phrases like 'distance moved from the rest position' which could include any number of oscillations and therefore be any number of values.

(ii) Most candidates were awarded credit for this question.

(b) (i) Some candidates looked to the wrong end of the line here and did not realise that, if the line is not straight at any point (for a particular amplitude), then the whole oscillation cannot be simple harmonic.

(ii) This was well answered in general but there were many power-of-ten errors. A few candidates did not use the correct relationship between ω and f.

(c) In general, candidates realised the graph would be of a circular shape.

Question 5

(a) (i) Many candidates were able to suggest two functions of the copper braid. It is important that candidates refer to the signal when answering this question.

(ii) Naming a single device does not answer this question completely. Stronger candidates gave answers in which they showed that one device must be connected to another using a coaxial cable, for example a satellite dish and a television.

(b) (i) This calculation was completed well. A few weaker candidates had the ratio of the powers upside down.

(ii) Again, this was answered well by most candidates.

Question 6

(a) Most candidates were able to state the required equation and name the other symbol used, which was the permittivity of free space. A significant number of candidates did not square r in the formula.

(b) (i) Candidates generally found this question difficult. It is probably easiest to think in terms of what the field strength would be like if the charges had the same signs – there would be a point of zero electric field strength at the neutral point. The key to showing that the charges are opposite was that the field strength was always positive; this was not well explained in general.

(ii) Most candidates realised here that the symmetry of the curve was the indicator of equal magnitude.

(c) In general, candidates realised that the acceleration was decreasing and then increasing, but were not always clear as to where. The fact that the acceleration was a <u>non-zero</u> minimum at 5.0 cm was missed by most candidates. The explanation of the link between electric field strength and acceleration was not given by many candidates.

Question 7

(a) (i) This was generally well answered, although a considerable number of candidates forgot to mention that all frequencies have the same gain.

(ii) Candidates found this more difficult. Some tried to link V_{IN} and V_{OUT} and others thought the question was about slew rate.

(b) (i) Most candidates could perform this calculation. Some weaker candidates used the equation for the inverting amplifier and so could not be awarded credit.

(ii) This question was well answered.

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(iii) This question was well answered.

(iv) Many weaker candidates assumed the p.d. across the resistor would be 2.2 V and so they calculated the resistance of the diode, not the resistance of resistor R.

Question 8

(a) Many candidates were not able to draw the correct field lines. In general, many candidates gained credit for the idea of concentric circles and also indicated the correct direction. Very few drew the circles sufficiently clearly to gain credit for the idea of increasing spacing.

(b) (i) Candidates were able to use the relationship given here, but many were not able to work out which current to use. In order to find the flux density at Q due to the current in P, they often used the current in Q instead.

(ii) Some candidates used the same current again in $F / L = BI$ when finding the force per unit length.

(c) This is an example of an application of Newton's third law, and those who realised this were usually successful. Many weaker candidates thought that the forces will be different because the currents in the wires are different.

Question 9

(a) Candidates often knew that precession was important, but some referred to atoms or molecules instead of nuclei or protons.

(b) Many candidates knew that the non-uniform field was used to locate the position of the nuclei.

Question 10

(a) (i) Candidates generally did well here to interpret an unfamiliar presentation of the bridge rectifier circuit.

(ii) Most candidates were able to calculate the maximum p.d. across R, i.e. the peak p.d.

(b) (i) Many candidates were able to draw the correct diode symbol and place it in parallel with resistor R.

(ii) 1. Candidates were often confused between V, the ripple and the magnitude of the ripple. Most candidates did realise that the magnitude of the ripple would decrease here.

2. Very few candidates realised that the magnitude of the ripple would increase. The size of V_{MAX} is fixed by the power supply, so this cannot change. The discharge is faster when the resistance of R is smaller so the curve will drop more in the same time.

Question 11

(a) This was very well answered by the majority of candidates.

(b) (i) 1. This calculation was carried out correctly by most candidates.

2. Many candidates subtracted the work function energy from the photon energy here to find the maximum kinetic energy of the emitted electrons. Some weaker candidates equated the photon energy or the work function energy to the maximum kinetic energy and could not be awarded credit.

(ii) Many candidates did not demonstrate good knowledge here. Common misconceptions were that some energy was lost as heat or because of friction.

(c) This table proved to be a good test of knowledge and reasoning. Many candidates did not realise that, for the same intensity, the number of photons per second must go down if the frequency goes up, as each photon has more energy.

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Question 12

(a) It is very important that, when candidates are given a 'show that' question, they substitute in all the values and show clearly every stage of the working. A significant number of candidates did not show the use of 1.6×10^{-19} or the conversion from eV to MeV.

(b) (i) This calculation was carried out correctly by most candidates.

(ii) Candidates answered this question well, showing good knowledge of the shape of the curve of binding energy per nucleon.

(c) Candidates found this calculation challenging. A large number of candidates tried to do this calculation by finding the total masses on both sides of the equation and then finding the mass defect, but there was not enough data for this approach. There were two correct ways of approaching this calculation – either by using the mass defects given and multiplying by 934, or by finding the total binding energies on both sides. Neutrons and electrons do not have binding energies.

(d) Only the strongest candidates successfully completed this calculation. Some gained partial credit for the number of nuclei in 1.2×10^{-7} mol of uranium-235. Some also gained partial credit for the energy released in one reaction in J. Only a small number of candidates were able to put all three stages together correctly.

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Paper 9702/42
A Level Structured Questions

Key messages

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

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

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

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

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

General comments

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

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

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Comments on specific questions

Question 1

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

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

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

Question 2

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

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

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

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

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

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

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Question 3

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

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

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

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

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

Question 4

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

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

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

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

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

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

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Question 5

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

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

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

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

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

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

Question 6

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

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

Question 7

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

Question 8

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

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

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

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

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

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

Question 9

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

(b) (i) Many candidates were able to successfully convert 4.8 MeV to J, although some made a mistake with the power of ten represented by the mega prefix. A significant number of the weaker candidates attempted to answer the question using $E_k = ½mv^2$.

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

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

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

Question 10

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

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

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

Question 11

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

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

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

Question 12

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

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

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

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

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PHYSICS

Paper 9702/43
A Level Structured Questions

Key messages

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

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

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

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

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

General comments

There was a wide spread in the standard of candidates, with marks awarded across the full mark range. Candidates managed their time well with little evidence of candidates not being able to complete the paper.

There were many answers where candidates attempted to write all that they knew rather than focusing on answering the question. This should be discouraged as it not a good way of approaching the paper.

Working for calculations was nearly always shown, which is encouraging, and use of English was very good in general.

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Comments on specific questions

Question 1

(a) Although well answered by many candidates, the most common omission was the fact that the masses involved are point masses.

(b) (i) Many candidates were able to state features of the orbit of a geostationary satellite. Some weaker candidates repeated ideas already within the question and some just rephrased what geostationary means, i.e. above the same point on the Earth at all times.

(ii) Many candidates did not meet the requirement to explain their working here. They need to begin with a fundamental principle they are applying, which here is that the gravitational force provides the centripetal force. The calculation was generally correct, but there were errors in forgetting to square the time period or cube the radius. Power-of-ten errors were also evident due to forgetting to convert the radius from km into m. A small but significant number of candidates started with the incorrect assumption that the gravitational field strength at the satellite would be $9.81\,N\,kg^{-1}$.

Question 2

(a) In general, most candidates received at least partial credit here. Candidates needed to be clear in their answers whether they were referring to the volume of one molecule or the volume of all of the molecules.

(b) (i) There were two approaches to this calculation. The first one, using $pV = NkT$, is more straightforward, but was used by a small number of candidates. A second approach, $pV = nRT$, involves a further step to go from the number of moles n to the number of molecules N. A common error was to confuse these two and to stop at 4.5. Candidates should realise that 4.5 cannot be a realistic answer for the number of molecules in a container of gas. Almost all candidates remembered to convert the temperature from Celsius into kelvin.

(ii) This was an estimation question. Some candidates gave their estimates to 3 significant figures, which was inappropriate given the precision of the data.

(c) In order to refer to their answer in **(b)(ii)**, candidates needed to include their numerical value and then compare this to the numerical value of the volume given. Simply saying that one was larger than the other was not sufficient as it does not justify the assumption.

Question 3

(a) Candidates knew that change of state occurs at constant temperature. Many candidates did not make clear that specific latent heat is the amount of energy per unit mass for this to happen. The amount of energy to change the state of 1 kg does not make it clear that division by mass is involved in the definition.

(b) (i) Most candidates were able to interpret the graph to determine the mass of liquid evaporated.

(ii) Candidates found it difficult to demonstrate the knowledge that rate of loss of thermal energy depends on the difference in temperature between the body and its surroundings. Here, with different power ratings, the temperature of the liquid was the same both times.

(iii) Candidates found this calculation challenging and many did not include the heat losses in their calculations. Other errors were not converting from minutes into seconds, using the wrong time interval such as 12 minutes and also using the incorrect change in mass.

(iv) This calculation was also challenging. Many candidates found the average of the two input powers or the difference between them.

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Question 4

(a) (i) Most candidates gave the idea that this was the distance from the central equilibrium position. Only a small number of candidates went on to say that the direction was needed as well. Some candidates used phrases like 'distance moved from the rest position' which could include any number of oscillations and therefore be any number of values.

(ii) Most candidates were awarded credit for this question.

(b) (i) Some candidates looked to the wrong end of the line here and did not realise that, if the line is not straight at any point (for a particular amplitude), then the whole oscillation cannot be simple harmonic.

(ii) This was well answered in general but there were many power-of-ten errors. A few candidates did not use the correct relationship between ω and f.

(c) In general, candidates realised the graph would be of a circular shape.

Question 5

(a) (i) Many candidates were able to suggest two functions of the copper braid. It is important that candidates refer to the signal when answering this question.

(ii) Naming a single device does not answer this question completely. Stronger candidates gave answers in which they showed that one device must be connected to another using a coaxial cable, for example a satellite dish and a television.

(b) (i) This calculation was completed well. A few weaker candidates had the ratio of the powers upside down.

(ii) Again, this was answered well by most candidates.

Question 6

(a) Most candidates were able to state the required equation and name the other symbol used, which was the permittivity of free space. A significant number of candidates did not square r in the formula.

(b) (i) Candidates generally found this question difficult. It is probably easiest to think in terms of what the field strength would be like if the charges had the same signs – there would be a point of zero electric field strength at the neutral point. The key to showing that the charges are opposite was that the field strength was always positive; this was not well explained in general.

(ii) Most candidates realised here that the symmetry of the curve was the indicator of equal magnitude.

(c) In general, candidates realised that the acceleration was decreasing and then increasing, but were not always clear as to where. The fact that the acceleration was a non-zero minimum at 5.0 cm was missed by most candidates. The explanation of the link between electric field strength and acceleration was not given by many candidates.

Question 7

(a) (i) This was generally well answered, although a considerable number of candidates forgot to mention that all frequencies have the same gain.

(ii) Candidates found this more difficult. Some tried to link V_{IN} and V_{OUT} and others thought the question was about slew rate.

(b) (i) Most candidates could perform this calculation. Some weaker candidates used the equation for the inverting amplifier and so could not be awarded credit.

(ii) This question was well answered.

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(iii) This question was well answered.

(iv) Many weaker candidates assumed the p.d. across the resistor would be 2.2 V and so they calculated the resistance of the diode, not the resistance of resistor R.

Question 8

(a) Many candidates were not able to draw the correct field lines. In general, many candidates gained credit for the idea of concentric circles and also indicated the correct direction. Very few drew the circles sufficiently clearly to gain credit for the idea of increasing spacing.

(b) (i) Candidates were able to use the relationship given here, but many were not able to work out which current to use. In order to find the flux density at Q due to the current in P, they often used the current in Q instead.

(ii) Some candidates used the same current again in $F / L = BI$ when finding the force per unit length.

(c) This is an example of an application of Newton's third law, and those who realised this were usually successful. Many weaker candidates thought that the forces will be different because the currents in the wires are different.

Question 9

(a) Candidates often knew that precession was important, but some referred to atoms or molecules instead of nuclei or protons.

(b) Many candidates knew that the non-uniform field was used to locate the position of the nuclei.

Question 10

(a) (i) Candidates generally did well here to interpret an unfamiliar presentation of the bridge rectifier circuit.

(ii) Most candidates were able to calculate the maximum p.d. across R, i.e. the peak p.d.

(b) (i) Many candidates were able to draw the correct diode symbol and place it in parallel with resistor R.

(ii) 1. Candidates were often confused between V, the ripple and the magnitude of the ripple. Most candidates did realise that the magnitude of the ripple would decrease here.

2. Very few candidates realised that the magnitude of the ripple would increase. The size of V_{MAX} is fixed by the power supply, so this cannot change. The discharge is faster when the resistance of R is smaller so the curve will drop more in the same time.

Question 11

(a) This was very well answered by the majority of candidates.

(b) (i) 1. This calculation was carried out correctly by most candidates.

2. Many candidates subtracted the work function energy from the photon energy here to find the maximum kinetic energy of the emitted electrons. Some weaker candidates equated the photon energy or the work function energy to the maximum kinetic energy and could not be awarded credit.

(ii) Many candidates did not demonstrate good knowledge here. Common misconceptions were that some energy was lost as heat or because of friction.

(c) This table proved to be a good test of knowledge and reasoning. Many candidates did not realise that, for the same intensity, the number of photons per second must go down if the frequency goes up, as each photon has more energy.

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Question 12

(a) It is very important that, when candidates are given a 'show that' question, they substitute in all the values and show clearly every stage of the working. A significant number of candidates did not show the use of 1.6×10^{-19} or the conversion from eV to MeV.

(b) (i) This calculation was carried out correctly by most candidates.

(ii) Candidates answered this question well, showing good knowledge of the shape of the curve of binding energy per nucleon.

(c) Candidates found this calculation challenging. A large number of candidates tried to do this calculation by finding the total masses on both sides of the equation and then finding the mass defect, but there was not enough data for this approach. There were two correct ways of approaching this calculation – either by using the mass defects given and multiplying by 934, or by finding the total binding energies on both sides. Neutrons and electrons do not have binding energies.

(d) Only the strongest candidates successfully completed this calculation. Some gained partial credit for the number of nuclei in 1.2×10^{-7} mol of uranium-235. Some also gained partial credit for the energy released in one reaction in J. Only a small number of candidates were able to put all three stages together correctly.

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PHYSICS

Paper 9702/51
Planning, Analysis and Evaluation

Key messages

- In **Question 1**, candidates' responses should include detailed explanations of experimental procedures such as how to control variables, how to take measurements and how to analyse the data.
- Graphical work should be carefully attempted and checked. Care is also needed when reading information from the graph.
- The numerical answers towards the end of **Question 2** require candidates to show all their working. A full understanding of significant figures and the treatment of uncertainties is required.
- The practical skills required for this paper should be developed and practised with a 'hands-on' approach throughout the course.

General comments

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

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

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

Comments on specific questions

Question 1

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

Candidates were awarded credit for a clearly labelled diagram. Diagrams should be drawn of the workable setup of the experiment. In this experiment, candidates needed to show clearly the air blower with the position of the ball and a method of measuring h, e.g. a vertical metre rule. Both the air blower and the ball

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needed to be labelled. Further credit was awarded for realising that the metre rule should be clamped and for clearly showing the position of a set square resting on a bench or horizontal surface.

Credit was given for the correct electrical circuit to find the power of the motor/air blower. In many cases no attempt was made to draw the circuit. The most common error was to include a resistor in the circuit and then position a voltmeter incorrectly so that it is not measuring the p.d. across the motor/air blower. Many candidates did not appreciate that the voltmeter was required to measure the p.d. across the motor/air blower. Credit for additional detail was awarded to candidates who then correctly indicated how the value of the power P could be calculated using the equation $P = VI$, where V needed to be defined as the p.d. across the motor/air blower. Some candidates also received credit for the correct circuit diagram for a wattmeter or a joulemeter with a stop-watch.

Most candidates gained credit for suggesting using either calipers or a micrometer screw gauge to measure the diameter of the ball. Some candidates referred to using these instruments to measure radius. Stronger candidates suggested repeating the measurements of the diameter in different directions and then finding the mean.

Candidates needed to explain how they would determine h, the distance between the centre of the ball in its stationary position and the top of the blower. It would be easier to read the position of the ball either from the top of the ball or the bottom of the ball. Some candidates suggested placing a mark on the centre of the ball without realising that the ball may not stay in the same orientation.

Many candidates selected the correct axes for a graph (often h against $1/r^3$) but there was a number of candidates who incorrectly suggested plotting h against r. Candidates must explicitly state the quantities to be plotted on each axis either in the text or on drawn axes – credit is not given for just writing $y = mx + c$ under an expression. Having suggested an appropriate graph, candidates needed to explain how the graph would confirm the suggested relationship. This required the words 'relationship is valid if' and the word 'straight' to describe the line passing through the origin. Candidates needed to explain how to determine a value of K from the experimental results. Some candidates correctly identified a relationship between K and the gradient but did not put K as the subject of the equation. Some candidates suggested other graphs to plot such as r^3 against $1/h$; appropriate reasoning and an equation for K gained credit. Similarly, some candidates suggested plotting lg h against lg r. This also could gain credit for both testing the relationship (in this case, if the relationship is true, then the graph should be a straight line with a gradient of –3) and for determining K correctly using the y-intercept.

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

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

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

Question 2

(a) Candidates who were mathematically competent were able to work through the algebra and achieve credit. There were many alternatives for the y-intercept. Weaker candidates should be encouraged to use the white space on the question paper to rearrange the equation into an equation of a straight line.

(b) Completing the table appeared to be challenging for candidates. Most candidates were able to calculate a value for T. Many candidates did not determine the absolute uncertainty in T correctly. When readings are repeated, the absolute uncertainty is equal to half the range of the values. For these data, the absolute uncertainty in T was ± 0.04 s.

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Candidates were then required to determine lg *T*. Since values of *t* were recorded to three significant figures, lg *T* should have been recorded to three (or four) decimal places. The final part of this question was to determine the absolute uncertainty in lg *T*.

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

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

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

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

(iv) The majority of the candidates who were awarded full credit set out their working clearly. Stronger candidates often substituted a data point from the gradient calculation in **(c)(iii)** into $y = mx + c$.

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

(e) Candidates needed to show clear and logical working for this question. Clear substitution of numbers into equations was needed to determine *M*.

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PHYSICS

Paper 9702/52
Planning, Analysis and Evaluation

Key messages

- In **Question 1**, candidates' responses should include detailed explanations of experimental procedures such as how to control variables, how to take measurements and how to analyse the data.
- Graphical work should be carefully attempted and checked. Care is also needed when reading information from the graph.
- The numerical answers towards the end of **Question 2** require candidates to show all their working. A full understanding of significant figures and the treatment of uncertainties is required.
- The practical skills required for this paper should be developed and practised with a 'hands-on' approach throughout the course.

General comments

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

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

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

Comments on specific questions

Question 1

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

Candidates were awarded credit for a clearly labelled diagram. Diagrams should be drawn of the workable setup of the experiment. In this experiment, candidates needed to show clearly a spring with the final position of the ball and a method of measuring h e.g. a vertical metre rule. Both the spring and the ball

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needed to be labelled. Further credit was awarded for the method of attaching the spring to the bench, for clamping the metre rule and for clearly showing the position of a set square on a bench or horizontal surface.

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

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

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

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

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

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

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

Question 2

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

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

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

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

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

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

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

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

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

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

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

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PHYSICS

Paper 9702/53
Planning, Analysis and Evaluation

Key messages

- In **Question 1**, candidates' responses should include detailed explanations of experimental procedures such as how to control variables, how to take measurements and how to analyse the data.
- Graphical work should be carefully attempted and checked. Care is also needed when reading information from the graph.
- The numerical answers towards the end of **Question 2** require candidates to show all their working. A full understanding of significant figures and the treatment of uncertainties is required.
- The practical skills required for this paper should be developed and practised with a 'hands-on' approach throughout the course.

General comments

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

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

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

Comments on specific questions

Question 1

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

Candidates were awarded credit for a clearly labelled diagram. Diagrams should be drawn of the workable setup of the experiment. In this experiment, candidates needed to show clearly the air blower with the position of the ball and a method of measuring *h*, e.g. a vertical metre rule. Both the air blower and the ball

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needed to be labelled. Further credit was awarded for realising that the metre rule should be clamped and for clearly showing the position of a set square resting on a bench or horizontal surface.

Credit was given for the correct electrical circuit to find the power of the motor/air blower. In many cases no attempt was made to draw the circuit. The most common error was to include a resistor in the circuit and then position a voltmeter incorrectly so that it is not measuring the p.d. across the motor/air blower. Many candidates did not appreciate that the voltmeter was required to measure the p.d. across the motor/air blower. Credit for additional detail was awarded to candidates who then correctly indicated how the value of the power P could be calculated using the equation $P = VI$, where V needed to be defined as the p.d. across the motor/air blower. Some candidates also received credit for the correct circuit diagram for a wattmeter or a joulemeter with a stop-watch.

Most candidates gained credit for suggesting using either calipers or a micrometer screw gauge to measure the diameter of the ball. Some candidates referred to using these instruments to measure radius. Stronger candidates suggested repeating the measurements of the diameter in different directions and then finding the mean.

Candidates needed to explain how they would determine h, the distance between the centre of the ball in its stationary position and the top of the blower. It would be easier to read the position of the ball either from the top of the ball or the bottom of the ball. Some candidates suggested placing a mark on the centre of the ball without realising that the ball may not stay in the same orientation.

Many candidates selected the correct axes for a graph (often h against $1/r^3$) but there was a number of candidates who incorrectly suggested plotting h against r. Candidates must explicitly state the quantities to be plotted on each axis either in the text or on drawn axes – credit is not given for just writing $y = mx + c$ under an expression. Having suggested an appropriate graph, candidates needed to explain how the graph would confirm the suggested relationship. This required the words 'relationship is valid if' and the word 'straight' to describe the line passing through the origin. Candidates needed to explain how to determine a value of K from the experimental results. Some candidates correctly identified a relationship between K and the gradient but did not put K as the subject of the equation. Some candidates suggested other graphs to plot such as r^3 against $1/h$; appropriate reasoning and an equation for K gained credit. Similarly, some candidates suggested plotting lg h against lg r. This also could gain credit for both testing the relationship (in this case, if the relationship is true, then the graph should be a straight line with a gradient of –3) and for determining K correctly using the y-intercept.

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

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

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

Question 2

(a) Candidates who were mathematically competent were able to work through the algebra and achieve credit. There were many alternatives for the y-intercept. Weaker candidates should be encouraged to use the white space on the question paper to rearrange the equation into an equation of a straight line.

(b) Completing the table appeared to be challenging for candidates. Most candidates were able to calculate a value for T. Many candidates did not determine the absolute uncertainty in T correctly. When readings are repeated, the absolute uncertainty is equal to half the range of the values. For these data, the absolute uncertainty in T was ± 0.04 s.

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Candidates were then required to determine lg *T*. Since values of *t* were recorded to three significant figures, lg *T* should have been recorded to three (or four) decimal places. The final part of this question was to determine the absolute uncertainty in lg *T*.

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

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

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

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

(iv) The majority of the candidates who were awarded full credit set out their working clearly. Stronger candidates often substituted a data point from the gradient calculation in **(c)(iii)** into $y = mx + c$.

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

(e) Candidates needed to show clear and logical working for this question. Clear substitution of numbers into equations was needed to determine *M*.

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