PHYSICS

Paper 9702/11
Multiple Choice

There were too few candidates for a meaningful report to be produced.

PHYSICS

Paper 9702/12
Multiple Choice

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

General comments

Candidates should always read each question through in its entirety before looking at the answer options, taking particular care when, for instance, a question asks 'which statement is **not** correct?'. All four answer options should be considered carefully, trying to justify eliminating three of the options as a check to make sure the answer selected is the correct one.

When answering numerical questions, it is a good idea to try to calculate the answer before looking at the answer options. Candidates need to ensure that the units used in a calculation are consistent, particularly if the information includes prefixes such as k, μ or M, or data which includes areas in mm^2 or cm^2 or volumes in mm^3 or cm^3.

Candidates found **Questions 5**, **11**, **21**, **26**, **30**, **34** and **37** particularly difficult. They found **Questions 4**, **20**, **28** and **39** relatively straightforward.

Comments on specific questions.

Question 1

Many candidates thought that kelvin was a physical quantity, but it is a unit for the physical quantity of temperature. The correct answer **D** is a physical quantity with a magnitude and a unit.

Question 3

Candidates who were incorrect often either calculated (4 / 250) × 100 = 1.6% (answer **A**) or (2 / 25) × 100 = 8% (answer **C**).

Question 5

Many candidates calculated the average **speed** of the toy car after 20 s and 40 s rather than the (magnitude of the) average **velocity**. In 20 s, the toy car travels a distance of 10 m but the displacement is ($20 / \pi$ =) 6.4 m, so the average velocity for the first 20 s is (6.4 / 20 =) 0.32 m s^{-1}.

After 40 s, the toy car has arrived back at its starting point, so its displacement, and hence its average velocity, is zero.

Question 7

Candidates found this question difficult. Let the time taken for the express train to catch up with the goods train be T seconds, at which point both trains will have travelled the same distance s. Applying $s = ut + \frac{1}{2}at^2$ for both trains:

(s =) $10T = \frac{1}{2} \times 0.5 \times T^2$.

Solving this gives T = 40 s, which is **D**.

Question 11

Many candidates found this question difficult, often choosing **B** rather than the correct answer **D**. They were familiar with the equation *velocity of separation equals velocity of approach* for an elastic collision, but did not appreciate that sphere X continues to travel in the **same direction** after the collision. The velocity of approach is 6 cm s^{-1} so sphere Y must move at a speed of 8 m s^{-1} after the collision (i.e. 6 cm s^{-1} faster than sphere X).

Question 19

For planet X, the change in gravitational potential energy of the mass m is $\Delta E = (mg_X) \times 3$.

Similarly, for the mass m on planet Y: $4\Delta E = (mg_Y) \times 4$.

Combining these two equations: $(mg_Y) \times 4 = 4 \times [(mg_X) \times 3]$ then leads to $g_Y = 3g_X$.

Question 21

Candidates found this question difficult and approximately equal numbers of candidates chose incorrect answers **B**, **C** and **D**.

As the wire obeys Hooke's law, a graph of force against extension with either variable on the x-axis would be a straight line, so **B** and **C** can be rejected.

The elastic potential energy E in a wire obeying Hooke's law is $E = \frac{1}{2}kx^2$ where x is the extension and k is the spring constant for the wire. Rearranging this equation gives $x = \sqrt{(2E / k)}$. If the extension is doubled, E would increase by a factor of 4, indicating that the correct graph is **A** rather than **D**.

Question 25

Most candidates recognised that an electromagnetic wave of wavelength of 5.0×10^{-2} m is in the microwave region of the electromagnetic spectrum, but many thought a wavelength of 5.0×10^{-7} m is in the ultraviolet region rather than the visible region of the spectrum. An approximate range for the visible part of the spectrum is 400–700 nm (0.4–0.7 µm).

Question 26

Candidates found this question difficult and almost half of the candidates selected the incorrect answer **B**.

The wavelength of the sound can be calculated by measuring the frequency of the sound and the speed of sound in air (answer **B**) but this is not the **least** possible number of quantities needed to determine the wavelength.

In a stationary sound wave, the distance between successive nodes (‘quiet spots’) is half a wavelength. The mean separation of the quiet spots can measured and then doubled to determine the wavelength. Only one measurement is needed in this method, so this is the determination of the wavelength using the least number of measured quantities.

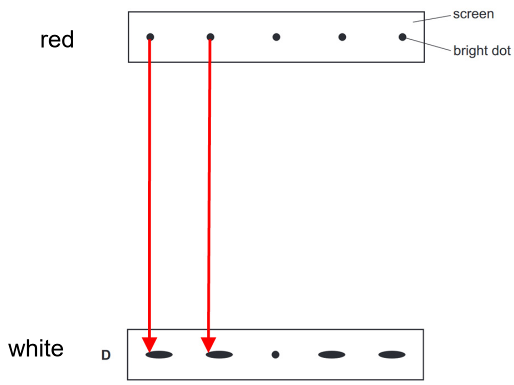
Question 29

Most candidates appear to have calculated the wavelength of the light waves (4.0×10^{-7} m) using the double-slit equation, but many did not interpret the significance of the second-order dark fringe correctly. The path difference must be an odd number of half-wavelengths for destructive interference to occur, which eliminates **B** and **D**. The path difference for the first-order dark fringe is $\frac{\lambda}{2}$ so the path difference for the second-order dark fringe is $\frac{3\lambda}{2}$. The correct answer is **C**: $\frac{3}{2} \times 4.0 \times 10^{-7} = 6.0 \times 10^{-7}$ m.

Question 30

Many candidates found this question difficult. If the red light of a single wavelength is replaced by blue light of a single wavelength, the pattern observed would be **A** with the maxima closer together. From the diffraction grating equation, θ is smaller for the shorter (blue) wavelength.

A source of white light consists of a range of wavelengths from blue to red, so white light will produce visible spectra as maxima (except for the central zero-order maximum) with the ends of the spectra in the same position as the blue and red maxima. This is the pattern shown in **D**.



Question 34

Candidates found this question difficult. Let the original length of the wire be l, its cross-sectional area A and the resistivity of the metal ρ. The resistance R of the unstretched wire is $\rho l / A$.

When the wire is stretched, the volume of the wire $V = Al$ remains constant and so:

cross-sectional area $A \rightarrow 0.94^2 A$
length of the wire $l \rightarrow l / 0.94^2$

The new resistance of the stretched wire is $\rho(l / 0.94^2) / (0.94^2 A) = (\rho l / A) / 0.94^4 = 1.28R$, which is **D**.

Question 37

Many candidates found this question difficult, with more candidates choosing **B** or **C** than the correct answer **A**.

Initially, the two thermistors have the same resistance *R*. X is then placed in a cold environment and its resistance increases to 2*R*; Y is placed in a warm environment and its resistance decreases to *R* / 2. The reading on the voltmeter is then given by:

$V = 20\,\text{mV} \times (R/2) / (R/2 + 2R) = 5\,\text{mV}$ (answer **A**).

PHYSICS

Paper 9702/13
Multiple Choice

Question Number	Key
1	B
2	B
3	C
4	D
5	A
6	B
7	D
8	D
9	A
10	B

Question Number	Key
11	D
12	D
13	B
14	C
15	B
16	B
17	C
18	B
19	C
20	A

Question Number	Key
21	A
22	C
23	B
24	A
25	C
26	B
27	C
28	C
29	D
30	D

Question Number	Key
31	D
32	A
33	C
34	B
35	C
36	C
37	B
38	A
39	D
40	D

General comments

Candidates should always read each question through in its entirety before looking at the answer options, taking particular care when, for instance, a question asks 'which statement is **not** correct?'. All four answer options should be considered carefully, trying to justify eliminating three of the options as a check to make sure the answer selected is the correct one.

When answering numerical questions, it is a good idea to try to calculate the answer before looking at the answer options. Candidates need to ensure that the units used in a calculation are consistent, particularly if the information includes prefixes such as k, μ or M, or data which includes areas in mm^2 or cm^2 or volumes in mm^3 or cm^3.

Candidates found **Questions 3**, **10**, **20**, **21**, **36** and **37** particularly difficult. They found **Questions 4**, **7**, **11**, **16**, **22**, **23** and **35** relatively straightforward.

Comments on specific questions

Question 3

Many candidates found this question difficult. The meter has an accuracy of ±1%, so the largest (true) value of current is $1.01 \times 3.08 = 3.11$ A. The smallest value is $0.99 \times 3.04 = 3.01$ A. The true value of the current is the mean value with its uncertainty, i.e. (3.06 ± 0.05) A.

Question 5

Most candidates recognised that the vertical component of velocity v_V of the stone increases and the horizontal component of velocity v_H is constant, eliminating **B** and **D**. In the absence of air resistance, the stone falls with a constant acceleration g, and therefore v_V increases linearly with time, so graph **A** rather than graph **C** is correct.

Question 8

Just over half the candidates answered this question correctly, with a third of the candidates selecting the incorrect answer **C**. These candidates did not appreciate that the change in **velocity** of the ball is 20 $m\,s^{-1}$, not 4 $m\,s^{-1}$, when calculating the rate of change of momentum of the ball.

Question 9

Most candidates recognised that, as the air bubble is rising with terminal (constant) velocity, $X = Y + Z$.

The upthrust X is equal to the weight of the water displaced by the air bubble, which is much greater than the weight of the bubble. This implies that Z, the larger force acting downwards, is the viscous force on the bubble and Y is the weight of the bubble, which is **A**.

Question 10

Candidates found this question difficult and many chose **C** or **D** rather than the correct answer **B**. The two situations each have the same total momentum before impact, and momentum is conserved so they have the same total momentum after impact. Because the ball rebounds from the steel block, this ball has momentum to the left and so the steel block after impact **must** have greater momentum than the wooden block and embedded ball after impact. The wooden and steel blocks have equal mass, so it follows that the steel block **must** have a higher speed than the wooden block after the impact. Answer **B** is correct.

Question 13

A key point is to recognise that the rod is uniform, i.e. the centre of mass of the rod is at its centre, not at one end. Applying the principle of moments about the hinge: $T \times 30 \sin 40° = 5.2 \times 15$, and solving this gives $T = 4.0$ N, answer **B**.

Question 15

Just over half of the candidates answered this question correctly. The pressure exerted by the weight of the cube is:

pressure = weight / area = density × volume × g / area.

For a cube, volume = (side length)^3 and area = (side length)^2 and so it follows that the pressure exerted is the product of the acceleration of free fall, the density and the side length of the cube.

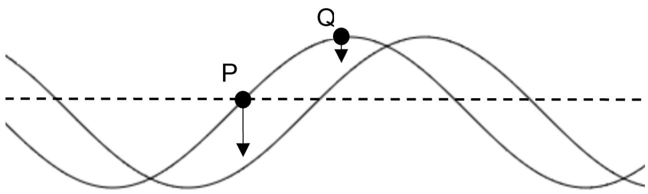
Question 20

Less than half of the candidates answered this question correctly. Most candidates calculated the extension of the two springs correctly, but some calculated the elastic potential energy stored in just one spring rather than the total elastic potential energy in the two springs.

For a single spring stretched a distance x by a force F, the elastic potential energy stored in the spring is $E_P = ½Fx$. As the two springs are in parallel, the force exerted on each individual spring is $F/2$. The extension of each spring is $x/2$. The total elastic potential energy stored in the two springs is $2 \times [½ \times (F/2) \times (x/2)]$ which is $E_P / 2$.

Question 21

Less than half of the candidates answered this question correctly. One approach is to draw the position of the wave a short time later than that shown in the question.



As the direction of the wave is towards the right, point P must be moving downwards. Point Q is momentarily stationary at the maximum upwards displacement (and will start to move down). The correct answer is **A**.

Question 24

This question proved to be difficult. The range of wavelengths of visible light is approximately 400–700 nm (0.4–0.7 μm). An electromagnetic wave of length equal to that of algae (0.5 μm) is in the visible range of the electromagnetic spectrum.

Question 27

Just over half the candidates answered this question correctly. The most diffraction occurs when the width of the gap is the same size as the wavelength of the waves. Halving the frequency of the sound wave doubles the wavelength from 0.50 m to 1.0 m – the same size as the width of the door.

Question 31

Just under half the candidates answered this question correctly. Most candidates calculated the energy supplied to the external resistor correctly (24 J) but did not calculate the e.m.f. of the battery correctly.

The energy dissipated in the external resistor is $I^2Rt = (40 \times 10^{-3})^2 \times 250 \times 60 = 24$ J.

If 6.0 J of energy is dissipated in the internal resistance r, then using $I^2rt = 6.0$ J gives $r = 62.5\,\Omega$.

If E is the e.m.f. of the battery, then $E = I(R + r)$ and this can be solved with the value of $r = 62.5\,\Omega$ to obtain $E = 12.5$ V, which is **D**.

Question 36

Less than half the candidates answered this question correctly, with many selecting **B** rather than the correct answer **C**.

Using the polarities of the batteries as shown in the circuit diagram, the overall e.m.f. in the circuit is 6.3 + 9.6 – 8.4 = 7.5 V. The current in the circuit is then $I = 7.5 / 3R$ where R is the resistance of each of the resistors.

The potential difference between P and Q is $V_{PQ} = 9.6 - (7.5 / 3R) \times R = 7.1$ V (answer **C**).

Question 37

In the original arrangement, the potential at the movable connection Z will vary from 0 to 2 V as the connection is moved from the left-hand end of the resistance wire to the right. When the new cell is connected between P and Q, the galvanometer reading will be zero when Z is very close to the left-hand end of the wire, so it will not be possible to determine a precise value of the e.m.f. of the new source by measuring a distance along the wire.

Adding resistances in series with the new source will not change the position of Z needed for a galvanometer reading of zero, so **C** and **D** may be eliminated.

Adding a large resistance in series with cell E will reduce the potential difference across the resistance wire. After adding the 1000 Ω resistor (answer **B**), the potential will vary from 0 to 20 mV along the length of the wire and this will enable a much more precise value of the e.m.f. of the new cell to be obtained.

Question 39

The majority of the candidates recalled that in β^+ decay a neutrino is emitted, but some confused β^+ and β^- decay in deducing the change to the proton number of the nucleus. In β^+ decay, a proton in the nucleus changes to a neutron, and emits a positron and a neutrino. The proton number of Y is one less than the proton number of X. i.e. the proton number of nucleus X is $Z + 1$.

Question 40

The majority of the candidates answered this question correctly, but some candidates determined that the charge of the particle is $+e$ rather than $+2e$. The charge on both an up quark and a charm quark is $+(2/3)e$. The charge on the particle described is $+(2/3)e + (2/3)e + (2/3)e = +2e$ (answer **D**).

PHYSICS

Paper 9702/21
AS Level Structured Questions

Key messages

- Candidates need to be able to recall in precise detail all the definitions, laws and basic formulae given in the syllabus. Without this basic knowledge it is impossible to access many of the questions in the examination.
- In numerical calculations, candidates should remember to first write down the relevant symbol equation before substituting in the numerical values.
- It is expected that candidates will be able to use the mathematical skills and knowledge referred to in Section 6 of the syllabus. This includes recalling the formula for the volume of a sphere and being able to sketch graphs of common simple expressions such as $y = kx^2$.
- The number of significant figures in the question data can be used as a guide to the number of significant figures required in the final answer. In the majority of cases, answers need to be given to a minimum of two significant figures.

General comments

The stronger candidates were generally successful in applying their knowledge to the questions. Some of the weaker candidates could have significantly improved their performance by being able to recall all the basic formulae.

In **Question 5**, a significant number of candidates found it challenging to apply their knowledge of wave polarisation and wave intensity. In **Question 6**, many candidates did not have a full understanding of an electrical circuit containing filament lamps.

Comments on specific questions

Question 1

(a) Although there were many fully correct answers, weaker candidates sometimes confused a unit with a quantity. Those candidates tended to wrongly indicate that force was a derived unit and that coulomb was a derived quantity.

(b) (i) Successful candidates were able to state that measurements are precise when they have a small range. The most common mistake was to describe accurate measurements rather than precise measurements.

(ii) In general, accuracy was less well understood than precision. The candidates needed to state what is meant by 'not accurate' measurements in the specific context of a physics experiment. Very weak candidates tended to give only vague statements. For example, some candidates vaguely stated that inaccurate measurements meant 'measurements not taken correctly' or 'measurements from a poor experiment'.

(c) (i) Most candidates realised that they needed to first add the percentage uncertainties of the quantities F, m and r, although a reasonable number did not realise that they then needed to divide the total by two. Another common error was to subtract, rather than add, the percentage uncertainty of m.

(ii) The majority of the candidates knew how to calculate the absolute uncertainty from the percentage uncertainty.

Question 2

(a) (i) The time taken for the ball to reach the ground was usually calculated correctly by using the horizontal component of the ball's velocity and the horizontal distance travelled. A common mistake was to not convert the horizontal distance units from cm to m. Weaker candidates tended to confuse the horizontal motion of the ball with its vertical motion.

(ii) Most candidates realised that the vertical component of the velocity of the ball as it hits the ground could be found by using an equation representing uniformly accelerated vertical motion. The most common error was to use the ball's initial horizontal velocity as its initial vertical velocity.

(iii) A significant number of candidates did not attempt a response this question. Most of the candidates who did attempt a response correctly used Pythagoras' theorem to determine the speed of the ball as it hits the ground and used an appropriate trigonometric function to find the angle of the ball's velocity to the horizontal.

(b) (i) The density of the steel was usually calculated correctly. Although the formula for density was well known, a significant proportion of the candidates were unable to recall the formula for the volume of a sphere. This is one of the mathematical requirements listed in Section 6 of the syllabus.

(ii) The majority of the candidates were able to successfully recall and apply the formula for kinetic energy. In general, candidates should remember to first write down the relevant symbol expression before writing down the numerical expression. There is then less chance of making a mistake when substituting in the numerical values.

(iii) The vast majority of the candidates knew how to calculate the spring constant from the graph. Sometimes a power-of-ten error was made by not converting the compression units from cm to m.

(iv) Those candidates who were able to recall the correct formula for the elastic potential energy stored in a spring were usually able to achieve full credit.

(c) (i) A common successful explanation was that the spring exerts the same average force on the polystyrene ball, so the smaller mass of the ball leads to a greater average acceleration, and this causes it to leave the spring with a greater speed. A small minority of candidates considered energy transfer and successfully explained that the polystyrene ball would have the same kinetic energy, so its smaller mass would cause it to leave the spring with greater speed.

(ii) Most candidates found this final question very challenging. Only a small minority realised that the polystyrene ball would have a smaller average vertical component of acceleration so that it would take a longer time to reach the ground than the steel ball.

Question 3

(a) (i) Power is defined as the work done per unit time. A significant minority of candidates gave inappropriate word equations that may be used for calculating power, but which do not define power (such as 'force × velocity' or 'current × potential difference').

(ii) Most candidates were able to derive $P = Fv$. A small number attempted to show only that P has the same base units as Fv, which did not answer the question.

(b) The majority of the candidates found it very straightforward to show the correct value of the resistive force opposing the forward motion of the lorry.

(c) (i) Only a minority of the candidates were able to successfully determine an expression for the component of the weight parallel to the road. A common incorrect expression was $mg \cos\theta$ instead of $mg \sin\theta$.

(ii) Many of the stronger candidates gave fully correct answers. A common mistake was to calculate only the power needed by the engine to do work against the component of the lorry's weight acting along the slope. This ignores the additional power needed by the engine to do work against the total resistive force acting on the lorry.

Question 4

(a) (i) In general, candidates found it difficult to state the precise meaning of polarisation.

(ii) Successful responses stated that light waves are transverse **and** that sound waves are longitudinal.

(b) Only a small proportion of the candidates were able to recall the symbol equation representing Malus's law. Those candidates who were able to recall the basic symbol equation often had difficulty in applying it to the question.

(c) (i) Some candidates released that the two waves would have different amplitudes because they had different intensities. However, very few candidates went on to explain why different amplitudes would prevent a stationary wave being formed.

(ii) A significant number of candidates did not attempt a response to this part of the question. Many of the candidates who did attempt a response were able to recall the general relationship between the intensity and the amplitude of a wave. However, most candidates found it challenging to fully apply this knowledge.

Question 5

(a) The majority of the candidates were unable to recall Ohm's law. A common mistake was to simply state Ohm's law as 'the potential difference is equal to the product of current and resistance'.

(b) (i) The graph shows that the resistance increases with potential difference because there is an increase in the ratio of the potential difference to the current. A common, but incorrect, assumption was that the resistance is inversely proportional to the gradient of the graph.

(ii) Only a small proportion of the candidates understood that the resistance increases because the temperature of the filament of the lamp increases.

(c) (i) Successful candidates realised that the current in each lamp could be determined from the graph. The most common incorrect answers were 0.89 A (obtained by assuming that the lamps and the potentiometer have the same current) and 1.78 A (obtained by assuming that the potentiometer has no current).

(ii) Candidates who were able to recall a correct symbol equation for power were usually able to apply it correctly.

(iii) Many candidates did not realise that, in order to calculate the resistance of the potentiometer, it was first necessary to find the current in the potentiometer by applying Kirchhoff's first law.

(d) In general, the effect on the brightness of the lamps of moving the potentiometer slider to end A was poorly understood. A common misconception was that this would make lamp P brighter and lamp Q less bright, which is the opposite of what actually occurs.

Question 6

(a) A fundamental particle is a particle which cannot be broken down into anything smaller. It is insufficient to state only that a fundamental particle is used to build other particles.

(b) Those candidates who were able to recall the charges of the three quarks were usually able to go on to show that the charge of the lambda particle is zero.

(c) (i) There were a variety of properties that could be used to compare an up quark and an up antiquark. The most common correct response was that their charges have the same magnitude, but opposite signs. Many candidates correctly stated that they had the same mass.

(ii) A significant number of candidates did not attempt a response this question. Most of the candidates who did attempt a response knew that a baryon is composed of three quarks. The general composition of a meson was less well known.

PHYSICS

Paper 9702/22
AS Level Structured Questions

Key messages

- Candidates need to be able to recall in precise detail all the definitions, laws and basic formulae given in the syllabus. Without this basic knowledge it is impossible to access many of the questions in the examination.
- In numerical calculations, candidates should remember to first write down the relevant symbol equation before substituting in the numerical values.
- It is expected that candidates will be able to use the mathematical skills and knowledge referred to in Section 6 of the syllabus. This includes recalling the formula for the volume of a sphere and being able to sketch graphs of common simple expressions such as $y = kx^2$.
- The number of significant figures in the question data can be used as a guide to the number of significant figures required in the final answer. In the majority of cases, answers need to be given to a minimum of two significant figures.

General comments

All of the questions contained straightforward parts that gave weaker candidates a chance to be awarded credit. Other parts of questions were more challenging. In **Question 5(b)(i)**, most candidates did not understand how the position of a string with a stationary wave on it would vary with time. In **Question 5(c)**, many candidates were unable to recall and apply the equation representing Malus's law to a beam of polarised light passing through two polarising filters.

There was no evidence of candidates having insufficient time to complete all the questions.

Comments on specific questions

Question 1

(a) Stronger candidates correctly stated that work done is the product of force and displacement in the direction of the force. Weaker candidates sometimes mentioned the displacement without referring to its direction. Others incorrectly referred to distance rather than displacement.

(b) The majority of the candidates were able to determine the correct answer. Some candidates left the newton as part of their answer without attempting to convert it into base units. Others did not read the question carefully and so determined the base units of work instead of the base units of power.

(c) (i) Generally, this question was well answered. The most common error was not converting the power units from kW to W.

(ii) This was a straightforward calculation for stronger candidates. Weaker candidates often added the percentage uncertainties in P and b, but did not realise that it was also necessary to divide by 3 in order to obtain the percentage uncertainty in v. Most candidates knew how to determine the absolute uncertainty from the percentage uncertainty.

Question 2

(a) Most candidates were able to apply the formula on the Formulae sheet for the upthrust on an object. However, weaker candidates were often unable to recall the formula for the volume of a sphere.

(b) The majority of the candidates realised that they could calculate the acceleration of the block by applying the equation $F = ma$. The most common error was to substitute into this equation the mass of the air displaced by the balloon instead of the mass of the block. Another common error was to substitute the upthrust acting on the balloon instead of the resultant force acting on the block.

(c) (i) Successful candidates tended to use the appropriate equation that represented uniformly accelerated motion in a straight line. Care needed to be taken with the signs of the substituted values. The most common error was to assume that the initial velocity of the block was zero instead of $1.4\,m\,s^{-1}$ upwards. Another common error was to assume that the final velocity of the block was zero. A very small number of candidates considered the transfer of energy and so correctly equated the increase in kinetic energy to the decrease in gravitational potential energy.

(ii) Some candidates realised that they needed to draw a straight line, but incorrectly started their line from the origin. Weaker candidates sometimes drew a curved line rather than a straight one, and did not appreciate that this would represent a changing acceleration rather than a constant acceleration.

Question 3

(a) The centre of gravity is the single point where all the weight of an object may be taken to act. Some candidates made the mistake of stating that it was the point where all the weight actually acts. Sometimes a reference was made to mass, instead of weight, leading to a description of the centre of mass instead of the centre of gravity.

(b) (i) The majority of answers were correct. The most common error was to calculate the horizontal component of the force instead of the vertical component.

(ii) Stronger candidates found it straightforward to apply the principle of moments. Weaker candidates incorrectly calculated the magnitude of at least one of the relevant moments. Difficulty was often encountered in calculating the correct perpendicular distance to the hinge of each force. A common error was to use the full length of the beam, instead of half the length, when calculating the moment due to the beam’s weight.

(iii) Although this was a simple calculation for the stronger candidates, the weaker candidates tended to simply guess an answer. A significant number incorrectly assumed that the horizontal component of the force would be zero.

(iv) Most responses were correct. A common incorrect response was that the tension would increase.

(v) The general formula for stress was usually recalled correctly. A significant number of candidates thought that increasing the radius of the wire by a factor of 3 would decrease the stress by a factor of 3, instead of by a factor of 9.

Question 4

(a) The formula for kinetic energy was usually recalled correctly. Sometimes a power-of-ten error was made by not converting the mass units from g to kg. Some candidates stated the correct symbol formula, but then did not square the value of the speed at the substitution stage.

(b) Weaker candidates were often unable to recall the general formula for the elastic potential energy of a spring. A common error was to assume that the maximum force acting on the spring was equal to the weight of the block.

(c) (i) Most candidates were able to calculate the momentum before the collision or the momentum after the collision. However, a common mistake was to then calculate the change in momentum by subtracting the magnitudes of the momenta. This ignores the change in direction of the momentum of the block. A significant minority of candidates inappropriately calculated the rate of change of momentum.

(ii) The resultant force was usually calculated correctly.

(d) Sketching the correct graph shape was challenging for most of the candidates. The most common incorrect shape was a straight line from the origin.

Question 5

(a) Stronger candidates realised that the two waves needed to be travelling in opposite directions. Weaker candidates often just guessed a condition or simply repeated one of the conditions that had already been given in the question.

(b) (i) This was one of the most challenging questions of the examination paper. The sketches drawn by many of the candidates suggested that they thought the wave was a progressive wave travelling from left to right, rather than an actual stationary wave.

(ii) The general symbol equation for determining the speed of a wave was usually recalled correctly. The most common mistake was to substitute into this equation an incorrect value of the wavelength.

(c) (i) Only a minority of the candidates were able to recall the general symbol equation representing Malus's law. Those candidates who could recall the general equation often had difficulty in applying it to the question. Sometimes the ratio was thought to be equal to $\cos 30°$ instead of $\cos^2 30°$.

(ii) A significant number of candidates did not attempt this part of the question and only the strongest candidates were able to calculate the correct ratio. Many candidates used a factor of $\cos^2 90°$ instead of $\cos^2 60°$, which then gave an incorrect final answer of zero.

Question 6

(a) The electric potential difference across a component may be defined as the energy transferred per unit charge. It is insufficient to define electric potential difference as 'the energy transferred by a unit charge' because this does not explicitly refer to a ratio of quantities and suggests that electric potential difference is an energy. Weaker candidates sometimes stated 'current × resistance' which is a formula for calculating potential difference, but does not define it.

(b) Although there were many partial explanations, only a minority of the candidates were able to give a full one. The full explanation needed to include an explicit comment that the resistors have the same current. A common misconception was that $P = V^2 / R$ means that the power dissipated is inversely proportional to resistance so that resistor Y dissipates the most power.

(c) (i) The majority of answers were fully correct.

(ii) Stronger candidates found it straightforward to recall and apply the appropriate formula. The most common error was to confuse the power dissipated in resistor P with the energy dissipated.

(iii) Only stronger candidates realised that they first needed to use Kirchhoff's first law to determine the current in the internal resistance. A common mistake was to assume that this current was equal to either the current in resistor P or the current in resistor Q. Only strongest candidates realised that they also needed to use Kirchhoff's second law to determine the potential difference across the internal resistance. A common error was to assume that this potential difference was equal to the electromotive force of the battery or the potential difference across resistor P.

Question 7

(a) Most candidates were able to give the number of neutrons and the number of protons in the nucleus. However, a significant number of candidates did not state the number of orbital electrons. It was important to consider the distinction between an atom and a nucleus. Very weak candidates often gave only a general description of the structure of any atom rather than a specific description of the structure of an atom of uranium-238.

(b) Nucleus X was usually identified correctly as consisting of two protons and two neutrons. Most candidates then realised that the charge of X would be twice the elementary charge. The calculation of the mass of X in units of kg proved to be more challenging.

(c) (i) Generally, this question was well answered. The most common incorrect answer was a down and two up quarks. Some candidates stated that particle P was a neutron, but did not answer the question by giving its quark composition.

(ii) This part of the question was slightly more challenging than **(c)(i)**, although most candidates were still able to state the correct quark composition.

PHYSICS

Paper 9702/23
AS Level Structured Questions

Key messages

- Candidates need to be able to recall in precise detail all the definitions, laws and basic formulae given in the syllabus. Without this basic knowledge it is impossible to access many of the questions in the examination.
- In numerical calculations, candidates should remember to first write down the relevant symbol equation before substituting in the numerical values.
- It is expected that candidates will be able to use the mathematical skills and knowledge referred to in Section 6 of the syllabus. This includes recalling the formula for the volume of a sphere and being able to sketch graphs of common simple expressions such as $y = kx^2$.
- The number of significant figures in the question data can be used as a guide to the number of significant figures required in the final answer. In the majority of cases, answers need to be given to a minimum of two significant figures.

General comments

Candidates should be encouraged to read questions carefully to ensure that their answers are appropriate in context, rather than simply repeating memorised extracts. For example, in **Question 4(d)(ii)**, many candidates described how stationary waves are formed rather than the ways in which they differ from progressive waves. In **Question 3(a)**, many candidates defined the moment of a force rather than stating the principle of moments.

In **Question 5**, candidates found it difficult to apply their understanding of electric circuits to an arrangement of cells connected in parallel. In **Question 6**, many candidates needed to improve their knowledge and understanding of fundamental particles.

There was no evidence of candidates lacking time to complete the paper.

Comments on specific questions

Question 1

(a) The majority of the candidates gave correct and well-presented solutions.

(b) Most candidates gave correct and clear responses. Although this part of the question used the command word 'show', a small proportion of the responses did not show why the uncertainty in the radius contributed 8% to the total percentage uncertainty.

(c) The majority of the candidates obtained at least some credit for their calculation. Many of the calculations by weaker candidates contained arithmetic and power-of-ten errors.

Question 2

(a) (i) Generally, this question was well answered. Some candidates chose points on the graph that were difficult to read instead of determining the gradient of the graph using exact values of velocity and time.

(ii) Stronger candidates found it straightforward to state the correct expression for the resultant force experienced by the rocket. Many weaker candidates thought that the resultant force was the sum of the magnitude of the thrust force and the magnitude of the weight even though these two forces act in opposite directions.

(iii) A large number of candidates made the mistake of equating the thrust force, rather than the resultant force, to the product of the mass and acceleration of the rocket. These candidates ignored the weight of the rocket.

(b) (i) The majority of the candidates were able to determine the correct height. The height could be obtained by applying an equation representing uniform acceleration or by calculating the area under the graph. Some candidates made the mistake of using the acceleration of free fall instead of the acceleration of the rocket in their calculations.

(ii) Only a minority of the candidates were able to calculate the correct speed. A common error was to assume that the initial velocity of the piece of metal was zero. Another common error was to use the initial acceleration of the rocket instead of the acceleration of free fall. Candidates needed to ensure that all values had the correct signs when they were substituted into the appropriate equation representing uniform acceleration.

Question 3

(a) Most candidates were able to state that the sum of the clockwise moments is equal to the sum of the anticlockwise moments. Candidates also needed to state that the moments are about the same point and that this is for an object in (rotational) equilibrium. A significant number of the candidates defined the moment of a force instead of stating the principle of moments.

(b) There were many correct answers. A common error was to calculate the moment by using the wrong component of the weight or by using the full weight.

(c) (i) The spring constant was usually calculated correctly. Some candidates made a power-of-ten error by not converting the compression units from millimetres to metres or by converting them incorrectly.

(ii) Generally, this question was well answered. Candidates needed to be able to recall the formula for the volume of a sphere, which is one of the mathematical requirements listed in Section 6 of the syllabus. There were some candidates who prematurely rounded the interim value of the volume during the calculation. This then led to an incorrect final answer for the upthrust acting on the sphere.

(iii) Most candidates were able to calculate at least one correct moment, but only the strongest candidates were able to correctly calculate all the moments acting on the system. Most calculations only included the moment due to the weight or the moment due to the upthrust. Only the strongest candidates included both moments.

(iv) Most candidates were able to correctly recall the appropriate formula for the elastic potential energy of a spring. However, only a minority of the candidates went on to substitute the correct values of force and extension. A common error was to use the maximum values of force and extension from the graph.

(d) A very small proportion of the candidates gave the correct response. There were many candidates who described energy losses due to heat even though the question stated that the resistive forces were negligible.

Question 4

(a) (i) The majority of the candidates drew circles around two appropriate particles. A small minority drew circles on the time axis which were not asked for in the question.

(ii) Most candidates found it difficult to draw a waveform with constant wavelength and amplitude. Only the stronger candidates realised that at zero distance the displacement of the wave would be negative with magnitude equal to the amplitude. A small minority of the candidates wrongly considered the wave to be a stationary wave and so drew a horizontal line.

(iii) Only a minority of the candidates stated the correct direction of motion of the particle. A common wrong answer was 'upwards' which implied confusion between the vertical displacement shown on the graph and the actual direction of displacement of the particle.

(b) The general formula for the speed of a wave was usually applied correctly. A common error was to assume that the wavelength of the wave was 0.19 m instead of 0.38 m.

(c) The general relationship between the intensity and the amplitude of a wave was usually recalled correctly. Arithmetic errors were often made when applying this general relationship to the question. A common incorrect answer was the inverse of the correct ratio.

(d) (i) Most candidates were able to give a correct condition. Weaker candidates often just guessed a condition or simply repeated the condition that had already been given in the stem of the question.

(ii) Candidates usually referred to stationary waves not transferring energy or having nodes and antinodes. Candidates found it more difficult to describe the variations in amplitude or phase difference for particles in a stationary wave compared with a progressive wave.

Question 5

(a) Most candidates correctly stated that the sum of the electromotive forces is equal to the sum of the potential differences. The candidates also needed to state that this is only true around a closed loop or closed circuit.

(b) (i) The majority of the candidates correctly attempted to calculate the total resistance due to the internal resistance of the three cells using the formula for resistors in parallel. A significant number then incorrectly calculated the resistance of the conductor by assuming that the conductor was in parallel with the cells instead of in series with them.

(ii) It was expected that the candidates would determine the current in the conductor by dividing the electromotive force of one cell by the total resistance of the circuit. Many candidates used only the resistance of the conductor in their calculation and ignored the internal resistance of the cells. Other candidates used an electromotive force of 4.5 V instead of 1.5 V in their calculation.

(c) (i) The ratio was usually calculated correctly. A common mistake was to assume that the area was proportional to the radius rather than the radius squared. A common incorrect answer was the inverse of the correct ratio. It was expected that the final answer would be expressed to two significant figures.

(ii) Most candidates were able to calculate the correct ratio. However, many candidates could not be awarded full credit as they did not explain their reasoning, even though the question asked them to do so. Candidates needed to explain that the average drift velocity is inversely proportional to the cross-sectional area because the current, the charge of a free electron and the number density of the free electrons are the same for both parts of the conductor.

(d) Candidates found this part of the question to be very challenging. Common misconceptions were that the effective electromotive force would decrease and that the total resistance of the circuit would decrease. Many candidates did refer to the resistance increasing or the current decreasing, but without making it clear in which part of the circuit this occurs.

Question 6

(a) Generally, this question was well answered. A significant minority of responses either did not have any values for the beta-particle or had incorrect values for the nuclide X.

(b) (i) Many candidates stated an inappropriate equation containing a neutron and a proton rather than an equation in terms of fundamental particles. A common error was to omit the antineutrino.

(ii) The candidates who answered **(b)(i)** correctly were usually able to show the conservation of charge.

(c) (i) Only a small minority of the candidates correctly referred to beta-particles having a continuous range of energies. A significant number of candidates did not attempt a response.

(ii) Many candidates appeared to have little knowledge of this topic and often a response was not attempted.

PHYSICS

Paper 9702/31
Advanced Practical Skills 1

Key messages

- If a raw value is out of trend to that expected, candidates should be encouraged to check the readings again with the equipment provided in the early stages of data collection.
- In the table work, the number of significant figures in the calculated quantity should relate to the number of significant figures in the raw data with the least number of significant figures. Each calculated quantity should be checked row by row.
- In the graphical work, candidates should be able to read off any points to the nearest half a small square. In particular, candidates should check carefully the read-offs of points used in the gradient calculation and when determining the *y*-intercept.
- When justifying a number of significant figures in a calculated quantity, candidates should relate the number of significant figures in the quantity to the raw readings used in the calculation. Candidates should not use the phrase ‘raw readings’ without explaining what those readings are, or attempt to use intermediate calculated quantities to justify the number of significant figures.
- To be successful answering **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. General points such as ‘measurements were difficult’ or ‘use more precise measuring instruments’ will not usually gain credit without further detail.

General comments

Centres did not generally 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 additional equipment should be available to the candidates. In some cases this may disadvantage candidates.

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

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

Comments on specific questions

Question 1

(a) Most candidates stated *d* with a unit and in the correct range. Some candidates omitted the unit.

(b) Many candidates recorded a final value of *T* with a unit and in the correct range. Stronger candidates also remembered to repeat their raw readings and to record at least two sets of 5*T*.

(c) Most candidates were able to collect six sets of values of *d* (to the nearest mm) and time with the correct trend. Stronger candidates chose a suitable range over which to conduct the experiment and extended their *d* values to less than 9.5 cm.

Many candidates gave both the quantity and correct unit for each heading, separated by a solidus or with brackets around the unit. A small number of candidates omitted the unit or the separating mark, or gave an incorrect unit e.g. T^2 / s instead of T^2 / s^2.

Generally, the table work was done well by candidates. The most difficult part was choosing an appropriate range over which to carry out the experiment.

(d) (i) Stronger candidates plotted the correct graph with suitable labels with plotted points occupying over half of the graph grid available.

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

Some candidates drew filled circles ('blobs') with a diameter greater than half a small square and some candidates did not plot their points within half a small square of the correct position. If a point seems anomalous, candidates should be encouraged to first check their plotting. If time permits and candidates do identify an anomalous point (having checked the plotting first), they should check their calculation. If the fault is still not identified, they should repeat the reading.

There is no credit specifically for identifying anomalous points, so candidates should be reminded that they do not need to identify an anomalous point if they do not think they have one.

(ii) Stronger candidates were able to draw carefully considered lines of best fit. There should always be a balanced distribution of points either side of the line along the entire length. Some lines needed a rotation or a shift to get a better fit, while other lines were not straight or too thick.

(iii) Candidates need to use a large triangle to calculate the gradient, use correct read-offs and substitute into a correct expression. Weaker candidates often used too small a triangle (the hypotenuse should be greater than half the length of the line drawn) and there were many instances of incorrect read-offs. Some candidates did not draw a triangle and instead attempted to use points from the table to determine the gradient.

Some candidates were able to correctly read off the *y*-intercept at $x = 0$ directly from the graph, but others incorrectly read off the *y*-intercept when there was a false origin (i.e. not $x = 0$). There were many instances of incorrect read-offs substituted into $y = mx + c$.

(e) Most candidates recognised that *A* and *B* were equal to the gradient and intercept respectively and stated these with the correct unit. Some candidates omitted the unit or gave an incorrect unit for *A*.

(f) Stronger candidates were able to calculate a value for *g*. Common mistakes were to give an incorrect unit or power of ten.

Question 2

(a) (i) Most candidates measured values of *l* in the appropriate range and to the nearest mm, and gave a consistent unit. A minority of candidates omitted the unit or stated the measurement to the nearest cm.

(ii) Many candidates stated *p* in range. A minority of candidates omitted the unit.

(iii) Many candidates calculated *R* correctly.

(b) Strong candidates correctly justified the number of significant figures they had given for the value of *R* with reference to the number of significant figures used in *p* and *l*. Many candidates gave reference to 'raw readings', 'previous measurements' or 'values used in calculation' but needed to detail the individual raw quantities concerned.

(c) (i) Many candidates stated a value of θ to the nearest degree and in the correct range. Some candidates stated the raw angle values to the nearest 0.1° when the protractor did not provide this precision.

(ii) Most candidates are familiar with the equation for calculating percentage uncertainty. Some candidates made an unrealistically small estimate of the absolute uncertainty in the value of θ, typically 1° or 2°. Some candidates repeated their readings and correctly gave the uncertainty in θ as half the range, showing clear working.

(d) Nearly all candidates recorded second values of l, p and θ with the second value of θ smaller than the first.

(e) Many candidates were able to calculate k for the two sets of data, showing their working clearly. Some candidates incorrectly rearranged the equation.

(f) Some candidates calculated the percentage difference between their values of k, testing it against the stated 10% criterion. Other candidates often omitted a percentage difference calculation, used a different criterion e.g. 20%, or gave concluding statements that were inconsistent with the calculation.

(g) (i) Candidates need to identify problems associated with setting up and obtaining readings. They can do this by writing about the different measurements taken or by chronologically going through the experiment systematically and stating clearly each difficulty. Candidates should then try to think of solutions that address each problem identified.

Some candidates identify a small number of problems (e.g. two) and become fixated on these without widening their responses. There is no additional credit for describing what is the essentially the same problem in several different ways.

Problems that were commonly given credit included ‘two sets of data were insufficient to draw a valid conclusion’ and ‘difficult to measure l or p as it is difficult to locate the centre of the putty’. Candidates often mentioned the problems without necessary detail or did not relate the difficulty to the quantity affected. For example, ‘hard to locate the centre of the putty’ needs some further reference to which measured quantity is affected by the problem. An answer such as ‘difficult to measure l’ cannot be given credit without a reason for the difficulty.

(ii) Improvements that were commonly seen were ‘take more readings and plot a graph’ and ‘clamp the ruler’. A solution, like a problem, needs to be given with enough detail to gain credit. Candidates are encouraged to turn vague statements that have relevance into detailed responses in order to gain credit. Careful consideration is needed.

Credit is not given for suggested improvements that could have been carried out in the original experiment e.g. ‘repeat readings’ or ‘view the ruler at right angles’.

PHYSICS

Paper 9702/33
Advanced Practical Skills 1

Key messages

- If a raw value is out of trend to that expected, candidates should be encouraged to check the readings again with the equipment provided in the early stages of data collection.
- In the table work, the number of significant figures in the calculated quantity should relate to the number of significant figures in the raw data with the least number of significant figures. Each calculated quantity should be checked row by row.
- In the graphical work, candidates should be able to read off any points to the nearest half a small square. In particular, candidates should check carefully the read-offs of points used in the gradient calculation and when determining the *y*-intercept.
- When justifying a number of significant figures in a calculated quantity, candidates should relate the number of significant figures in the quantity to the raw readings used in the calculation. Candidates should not use the phrase 'raw readings' without explaining what those readings are, or attempt to use intermediate calculated quantities to justify the number of significant figures.
- To be successful answering **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. General points such as 'measurements were difficult' or 'use more precise measuring instruments' will not usually gain credit without further detail.

General comments

Centres did not generally 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 additional equipment should be available to the candidates. In some cases this may disadvantage candidates.

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

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

Comments on specific questions

Question 1

(a) Most candidates stated E in the appropriate range and with a correct unit.

(b) Most candidates were able to collect six sets of values of x and V with the correct trend and without assistance from the Supervisor. Some candidates had V values with either the same value or out of trend for the increasing x values, indicating an incorrect circuit. Candidates should be encouraged to check the experimental setup again if the trend is not what is expected. A minority of candidates needed help setting up the circuit.

Many candidates chose too small a range over which to conduct the experiment. For example, starting from x = 45.0 cm up to either 70.0 cm (every 5.0 cm) or 95.0 cm (every 10.0 cm). This approach missed out on using lower possible values. Candidates should be encouraged to use the whole length of wire available.

Many candidates gave both the quantity and correct unit for each heading, separated by a solidus or with brackets around the unit. Some weaker candidates omitted the unit or separating mark, gave a comma as the separating mark, or gave an incorrect unit e.g. V instead of V^{-1} for the 1 / *V* column.

Candidates often did not appreciate that each row needed to be looked at on an individual basis and the significant figures in the calculated value of 1 / *V* needed to relate to the candidate's raw readings in *V*. Very often a value of raw *V* was given to three significant figures e.g. 3.25 but then 1 / *V* was stated to two significant figures e.g. 0.31. In doing so, the candidate is keeping the number of decimal places the same in the raw and calculated values, but for this calculation it is the significant figures, not the decimal places, that are important. This confusion between decimal places and significant figures is common.

In general, the table work was done well by candidates.

(c) (i) Stronger candidates plotted the correct graph with suitable labels and with plotted points occupying over half of the graph grid available.

Some candidates set the minimum value and maximum value of the scale on the graph grid to be the minimum and maximum readings in the table, leading to very time-consuming work plotting and using the scale. This type of scale cannot be awarded credit and it was very common for candidates using such awkward scales to lose further credit later for read-offs that were incorrect.

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

Some candidates drew filled circles ('blobs') with a diameter greater than half a small square and some candidates did not plot their points within half a small square of the correct position. If a point seems anomalous, candidates should be encouraged to first check their plotting. If time permits and candidates do identify an anomalous point (having checked the plotting first), they should check their calculation. If the fault is still not identified, they should repeat the reading.

There is no credit specifically for identifying anomalous points, so candidates should be reminded that they do not need to identify an anomalous point if they do not think they have one.

(ii) Stronger candidates were able to draw carefully considered lines of best fit. There should always be a balanced distribution of points either side of the line along the entire length. Some lines needed a rotation or a shift to get a better fit, while other lines were not straight or too thick.

(iii) Candidates need to use a large triangle to calculate the gradient, use correct read-offs and substitute into a correct expression. Weaker candidates often used too small a triangle (the hypotenuse should be greater than half the length of the line drawn) and there were many instances of incorrect read-offs. Some candidates did not draw a triangle and instead attempted to use points from the table to determine the gradient.

Some candidates were able to correctly read off the *y*-intercept at $x = 0$ directly from the graph, but others incorrectly read off the *y*-intercept when there was a false origin (i.e. not $x = 0$). There were many instances of incorrect read-offs substituted into $y = mx + c$.

(d) Most candidates recognised that *A* and *B* were equal to the gradient and *y*-intercept respectively.

(e) (i) Candidates would benefit from more practice in using micrometer screw gauges. Many candidates read the diameter from the micrometer incorrectly by misreading the main or thimble scale e.g. 0.83 mm instead of 0.33 mm. Some candidates omitted the unit or used an inconsistent unit, and so had a power of ten error e.g. 0.314 cm instead of 0.314 mm. Only the strongest candidates repeated their diameter readings.

(ii) Common mistakes were to omit π from the equation or to not square *d*. Some weaker candidates found *A* using πr^2 instead of transferring *A* from **(d)**. Candidates found it difficult to give a correct unit, and many candidates gave incorrect units of $\Omega\ m^{-1}$ or Ω.

Question 2

(a) (i) Most candidates measured values of L_1 in the appropriate range and to the nearest mm, and gave a consistent unit.

(ii) Most candidates are familiar with the equation for calculating percentage uncertainty. Some candidates made too small an estimate of the absolute uncertainty in the value of L_1, typically 1 mm. This is a difficult measurement, and a larger estimate of uncertainty would have been more appropriate. Some candidates stated an unrealistically large uncertainty e.g. 1 cm.

(iii) Many candidates calculated *k* correctly.

(iv) Stronger 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 *W* and $(L_1 – L_2)$ (or *W*, L_1 and L_2). Many candidates gave reference to 'raw readings', 'previous measurements', 'values used in calculation' or related to '*W* and *L*' but needed to provide more detail and state the individual raw quantities concerned.

(b) (i) Many candidates stated *M* in the appropriate range and calculated *V*. A very small number of candidates omitted the unit.

(ii) The majority of candidates correctly stated a value for L_{oil} that was less than L_{air}.

(iii) Most candidates recorded second values of *M*, L_{air} and L_{oil}. Nearly all candidates correctly recorded a larger second L_{air} value.

(c) Many candidates were able to calculate *Z* for the two sets of data, showing their working clearly. A minority of candidates incorrectly rearranged the equation.

(d) Stronger candidates calculated the percentage difference between their values of *Z*, testing it against the stated 5% criterion. Common mistakes were to omit a percentage difference calculation, use Z_1 / Z_2 incorrectly, give a different criterion e.g. 20%, or give conclusions that were not consistent with the calculation.

(e) Many candidates either used inconsistent units within the substitution (mixing the cm and m) or stated $g\ cm^{-3}$ for their answer instead of $kg\ cm^{-3}$ having used $g = 9.81\ N\ kg^{-1}$. Some very weak candidates confused density with resistivity units.

(f) (i) Candidates need to identify problems associated with setting up and obtaining readings. They can do this by writing about the different measurements taken or by chronologically going through the experiment systematically and stating clearly each difficulty. Candidates should then try to think of solutions that address each problem identified.

Some candidates identify a small number of problems (e.g. two) and become fixated on these without widening their responses. There is no additional credit for describing what is the essentially the same problem in several different ways.

Problems that were commonly given credit included 'two sets of data were insufficient to draw a valid conclusion', 'difficult to measure the length as holding the ruler by hand was hard to keep still' and 'parallax error in the length reading'. Candidates often mentioned the problems without necessary detail or did not relate the difficulty to the quantity affected. For example, an answer such as 'hard to keep ruler still by holding it' needs some reference to which quantity is affected by the problem (in this case the length).

(ii) Improvements that were commonly seen were 'take more readings and plot a graph' and 'clamp the ruler'. A solution, like a problem, needs to be given with enough detail to gain credit. Candidates are encouraged to turn vague statements that have relevance into detailed responses in order to gain credit. Careful consideration is needed.

Credit is not given for suggested improvements that could have been carried out in the original experiment e.g. 'repeat readings' or 'view the ruler at right angles'.

PHYSICS

Paper 9702/34
Advanced Practical Skills 2

Key messages

- If a raw value is out of trend to that expected, candidates should be encouraged to check the readings again with the equipment provided in the early stages of data collection.
- In the table work, the number of significant figures in the calculated quantity should relate to the number of significant figures in the raw data with the least number of significant figures. Each calculated quantity should be checked row by row.
- In the graphical work, candidates should be able to read off any points to the nearest half a small square. In particular, candidates should check carefully the read-offs of points used in the gradient calculation and when determining the *y*-intercept.
- When justifying a number of significant figures in a calculated quantity, candidates should relate the number of significant figures in the quantity to the raw readings used in the calculation. Candidates should not use the phrase 'raw readings' without explaining what those readings are, or attempt to use intermediate calculated quantities to justify the number of significant figures.
- To be successful answering **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. General points such as 'measurements were difficult' or 'use more precise measuring instruments' will not usually gain credit without further detail.

General comments

Centres did not generally 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 additional equipment should be available to the candidates. In some cases this may disadvantage candidates.

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

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

Comments on specific questions

Question 1

(a) (i) Most candidates were able to use the calipers to measure the thickness *T* correctly, giving their answer to the required precision and in the correct range. Some candidates would benefit from further familiarisation with calipers as a measuring device.

(ii) The majority of the candidates answered this question correctly, showing that they are able to use a ruler competently and record their answers giving the appropriate unit of measurement. A minority of candidates did not give the unit of the measured value.

(b) Repeated readings of the height *z* were required for credit, and many candidates gave repeated readings.

(c) In general, the table work was done well by candidates. The majority of the candidates were able to collect and record six sets of values of *T* and *z* with the correct trend and without the need for assistance. A minority collected more than six. Very few candidates collected five or fewer.

Many candidates did not make use of the maximum range of thickness *T* available. Candidates were given 1 cm of paper and the initial question related to 3 mm of paper. Candidates should be encouraged to decrease the independent variable and then increase it to the maximum value possible.

Table headings were generally correct and presented using accepted scientific convention. One common error was the omission of a suitable separating mark between the quantity and unit, for example writing θ° instead of θ/° or θ(°). Another common error was in providing a unit for the quantity cos θ. Some candidates omitted either the unit or the separating mark for the other columns.

A small minority of candidates gave their values for θ in radians.

Most candidates recorded their raw value for the dependent variable *z* to the correct precision i.e. to the nearest mm, which corresponds to the measuring equipment provided. Some candidates gave the measurement of *z* to 0.01 mm which is not consistent with the measuring equipment. Some candidates added on a trailing zero to the end of their number to make the number of significant figures the same down the column (e.g. 15.0, 9.00, 5.00 mm). This is not awarded credit as the number of decimal places in the raw readings of *z* must reflect the precision of the ruler used.

The majority of the candidates were able to give the calculated values of cos θ to three significant figures as instructed in the question. Candidates could be encouraged to underline the appropriate commands in the question e.g. "give your values of cos θ to <u>three significant figures</u>" if this helps them to remember an important point.

(d) (i) Many candidates plotted points carefully using a sharp pencil. A minority of candidates chose to plot points as 'blobs' (points with diameter greater than 1 mm) or chose awkward scales (axes labels with difficult increments e.g. 3, 6, 9, 12 etc.).

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

Some candidates omitted labels or marked their scales with large gaps between the labels (more than a large square). 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 sometimes 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. Any data recorded in the table must be plotted on the graph. Candidates must be careful to ensure that their axes are chosen such that **all** their table points can fit onto the graph grid they have chosen.

There is no credit specifically for identifying anomalous points, so candidates should be reminded that they do not need to identify an anomalous point if they do not think they have one.

The quality of the candidates' data was judged by the scatter of points about a straight-line trend. In the majority of cases this was good and so credit was awarded. Most candidates obtained results of the correct trend (negative) for this experiment and results remained close to the expected linear trend.

(ii) Stronger candidates were able to draw carefully considered lines of best fit. There should always be a balanced distribution of points either side of the line along the entire length. Some lines needed a rotation or a shift to get a better fit, while other lines were not straight or too thick.

(iii) Candidates need to use a large triangle to calculate the gradient, use correct read-offs and substitute into a correct expression. Weaker candidates often used too small a triangle (the hypotenuse should be greater than half the length of the line drawn) and there were many instances of incorrect read-offs. Some candidates did not draw a triangle and instead attempted to use points from the table to determine the gradient.

The sign of the gradient must match the trend of the line of best fit (i.e. in this question the expected trend was negative so the expected gradient sign was negative). The majority of the candidates included the minus sign in their final answer.

Some candidates were able to correctly read off the y-intercept at $x = 0$ directly from the graph, but others incorrectly read off the y-intercept when there was a false origin (i.e. not $x = 0$). There were many instances of incorrect read-offs substituted into $y = mx + c$.

(e) Candidates were expected to rearrange the equation given following the format of $y = mx + c$ to determine that the constant a corresponded to their intercept value (or c) and the constant b corresponded to the negative of their gradient value (or $-m$) from the previous page. Some candidates copied the gradient for a and intercept for b, which follows the same ordering of the answer lines but does not correspond to the correct answer.

A significant number of candidates either omitted units or included units for cos θ when determining the units of a and b.

Question 2

(a) (i) Most candidates measured values of h_0 in the correct range and gave a final value to the nearest mm. Some candidates incorrectly stated the measurement to the nearest 1 cm.

(ii) Most candidates correctly recorded a value of h which was smaller than h_0.

(iii) Many candidates are familiar with the equation for calculating percentage uncertainty and gave an uncertainty in d_m that was in the range deemed reasonable 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 d_m, typically 1 mm, or too large an estimate, typically 1.0 cm. Many candidates just used the uncertainty of 1 mm from the precision of the measuring instrument.

Some candidates repeated their readings and correctly gave the uncertainty in d_m as half the range, although other candidates did not halve the range when using this method.

Some candidates attempted to add the percentage uncertainty in h_0 and the percentage uncertainty in h. This method is not correct and was not awarded credit.

(b) (i) Many candidates correctly calculated S. Some candidates used a value of g of 9.8 $N\,kg^{-1}$ instead of the given value of 9.81 $N\,kg^{-1}$.

Some candidates truncated their answer instead of rounding correctly.

(ii) Candidates found it difficult to justify the number of significant figures they had given for the value of S with reference to the number of significant figures used in m, g and d_m (or h_0 and h). Many candidates stated 'raw readings' without making reference to what the raw quantity actually was.

(c) (i) Most candidates were able to take a reading for the height of the pointer above the bench.

Most candidates were able to record a reading for current to the required precision of the nearest 0.1 A and correctly gave the unit. Some candidates omitted the unit for current or gave the reading to the nearest ampere.

A minority of candidates were not awarded credit for the current reading as they had received assistance to set up the circuit.

(ii) The majority of the candidates were able to obtain a second reading for the height of the pointer above the bench and a second current reading. Most candidates correctly recorded a second value for *H* which was less than their first value.

(d) 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, gave their answer to only one significant figure or inadvertently substituted the wrong values.

(e) Many candidates calculated the percentage difference between their two values of *k*, then compared it to the specified numerical percentage uncertainty of 20% in order to give a statement about whether their results support the relationship or not.

Some candidates omitted the comparison with 20%, 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 percentage difference is less than 20%’.

Some candidates gave their own numerical percentage uncertainty which was not 20%. This could not be accepted. A small number of candidates made no attempt to use a calculation and just gave a conclusion. This also could not be accepted.

(f) (i) Candidates need to identify problems associated with setting up and obtaining readings. They can do this by writing about the different measurements taken or by chronologically going through the experiment systematically and stating clearly each difficulty. Candidates should then try to think of solutions that address each problem identified.

A large number of candidates recognised that the pointer oscillated, making it difficult to take an accurate reading for the height of the pointer. Candidates also often recognised that the current values fluctuated.

(ii) Candidates should be reminded of the need for clear communication when describing their improvements to an experiment. Vague references to size were not accepted; for example, candidates needed to write ‘stronger magnet’ instead of ‘bigger magnet’ or ‘wider test tube’ instead of ‘larger test tube’. They should be encouraged to use comparative adjectives when these are needed to describe their solutions, e.g. ‘use a strong<u>er</u> magnet’.

It is useful for candidates to remember to describe the method by which they will actually carry out a solution, e.g. ‘clean the contacts’ was not accepted but ‘clean the contacts with wire wool’ was accepted, as were other realistic methods of cleaning.

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 are also not given credit, e.g. ‘robotic arm’ or ‘mechanical hand’. Limitations that were irrelevant or that could have been removed if the candidate had taken greater care are also not given credit. Vague or generic answers such as ‘too few readings’ (without stating a consequence) or ‘use a set square/protractor’ (without stating what these would be used for) also cannot be given credit.

The key to this section is for candidates to identify genuine problems associated with setting up this experiment and in obtaining readings. Candidates are then encouraged to suggest practical solutions that either improve technique or give more reliable data. Clarity of thought and expression separated the stronger candidates from those less prepared to deal with practical situations and their limitations.

PHYSICS

Paper 9702/35
Advanced Practical Skills 1

Key messages

- If a raw value is out of trend to that expected, candidates should be encouraged to check the readings again with the equipment provided in the early stages of data collection.
- In the table work, the number of significant figures in the calculated quantity should relate to the number of significant figures in the raw data with the least number of significant figures. Each calculated quantity should be checked row by row.
- In the graphical work, candidates should be able to read off any points to the nearest half a small square. In particular, candidates should check carefully the read-offs of points used in the gradient calculation and when determining the *y*-intercept.
- When justifying a number of significant figures in a calculated quantity, candidates should relate the number of significant figures in the quantity to the raw readings used in the calculation. Candidates should not use the phrase 'raw readings' without explaining what those readings are, or attempt to use intermediate calculated quantities to justify the number of significant figures.
- To be successful answering **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. General points such as 'measurements were difficult' or 'use more precise measuring instruments' will not usually gain credit without further detail.

General comments

Centres did not generally 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 additional equipment should be available to the candidates. In some cases this may disadvantage candidates.

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

The general standard of the work done by the candidates was good, and there were many excellent scripts. Candidates did not seem to be short of time and both questions were attempted by almost all the candidates. They demonstrated good skills in the generation and handling of data. They could improve by plotting data points and taking read-offs with more care, and by giving more thought to the analysis and evaluation of experiments.

Comments on specific questions

Question 1

(a) Candidates had access to a 30 cm ruler and a metre rule, both of which had a millimetre scale. Many candidates set up the apparatus, gave raw L values to the nearest mm and correctly calculated a value for k.

(b) Many candidates were able to set up the apparatus and collect six sets of values of *a* and *L* without assistance from the Supervisor. These values were carefully recorded in their table of results and showed a correct trend in their values. Some candidates took the time to repeat their readings, and this helped to identify anomalous results and improve data quality. If time is limited, candidates should be encouraged to look out for possible outliers which do not fit a general trend and repeat these readings as they experiment to double-check.

Some candidates chose not to record *a* or *L* values but instead just recorded the calculated 1/*a* and *e* values. All raw data should be recorded. Candidates who do not record their raw data cannot be given credit for making recordings to the correct precision.

Many candidates chose *a* values that covered too small a range. It is expected that candidates look at their apparatus, to consider the whole range of possible *a* values that can be achieved and aim to use as wide a range as possible.

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

Candidates should take care to record all calculated values to the same number of significant figures as (or one more than) the number of significant figures in the raw data.

(c) (i) Most candidates plotted the correct graph with suitable labels with plotted points occupying over half of the graph grid available.

Some candidates set the minimum value and maximum value of the scale on the graph grid to be the minimum and maximum readings in the table, leading to very time-consuming work plotting and using the scale. This type of scale cannot be awarded credit and it was very common for candidates using such awkward scales to lose further credit later for read-offs that were incorrect.

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

Some candidates drew filled circles ('blobs') with a diameter greater than half a small square and some candidates did not plot their points within half a small square of the correct position. If a point seems anomalous, candidates should be encouraged to first check their plotting. If time permits and candidates do identify an anomalous point (having checked the plotting first), they should check their calculation. If the fault is still not identified, they should repeat the reading.

There is no credit specifically for identifying anomalous points, so candidates should be reminded that they do not need to identify an anomalous point if they do not think they have one.

(ii) Stronger candidates were able to draw carefully considered lines of best fit. There should always be a balanced distribution of points either side of the line along the entire length. Some lines needed a rotation or a shift to get a better fit, while other lines were not straight or too thick.

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

(iii) Candidates need to use a large triangle to calculate the gradient, use correct read-offs and substitute into a correct expression. Weaker candidates often used too small a triangle (the hypotenuse should be greater than half the length of the line drawn) and there were many instances of incorrect read-offs. Some candidates did not draw a triangle and instead attempted to use points from the table to determine the gradient.

Some candidates were able to correctly read off the y-intercept at $x = 0$ directly from the graph, but others incorrectly read off the y-intercept when there was a false origin (i.e. not $x = 0$). There were many instances of incorrect read-offs substituted into $y = mx + c$.

(d) (i) Many candidates recognised that *B* was equal to the gradient and *C* was equal to the intercept. Stronger candidates recorded values with consistent units, including correctly presenting *B* without a unit. Weaker candidates often stated an incorrect unit for *C* (often m) or omitted the unit.

(ii) Many candidates correctly calculated a value for *R*. Some candidates found it difficult to rearrange the equation correctly.

Question 2

(a) Candidates needed to carefully and correctly draw lines on the cardboard, then measure a value of *d* to the nearest mm. Candidates must remember that the final value of *d* should retain the precision of the raw readings. Some candidates gave readings to the nearest cm, or did not notice the unit and consequently gave a value outside the accepted range.

(b) (i) Most candidates measured and recorded a value of *p* in the required range, noticing that the unit given was m. Some candidates did not notice the unit and consequently gave a value outside the acceptable range.

Many candidates set up the apparatus correctly and were able to time oscillations. Many candidates repeated the timing of nT and noted all their readings of nT to the same precision. Credit was not given for timing a single oscillation several times. Many candidates then used an average value of nT to calculate a value of T in the required range. Some weaker candidates gave a value of T that was out of the correct range, either having forgotten to divide by n or having misread the stop-watch.

(ii) Most candidates are familiar with the equation for calculating percentage uncertainty.

Some candidates realised that, having timed nT, it was reasonable to estimate the absolute uncertainty in nT as 0.2–0.4 s. Many candidates forgot they had measured nT and gave the absolute uncertainty in T between 0.2–0.4 s, whereas this absolute uncertainty needed to be divided by n. Some candidates repeated their readings and correctly gave the uncertainty in T as half the range.

(iii) Most candidates calculated and recorded values correctly.

(iv) Stronger candidates correctly justified the number of significant figures they had given for the value of T^2p with reference to the number of significant figures used in p and time. Some candidates gave reference to only T^2, or 'raw readings', 'measured values' or 'values in the calculation' without specifically stating what these values were.

(v) Most candidates correctly recorded second values of p and T.

Many candidates correctly recorded values of T which showed an increase in the second value of T compared to the first value of T. For some candidates the second T showed the wrong trend with a decrease.

(c) Many candidates were able to calculate q for the two sets of data, showing their working clearly. A minority of candidates incorrectly rearranged the equation algebraically.

(d) Stronger candidates calculated the percentage difference between their values of q, testing it against the stated 15% criterion. Common mistakes were to omit a percentage difference calculation, use q_1 / q_2 incorrectly, give a different criterion e.g. 20%, or give conclusions that were not consistent with the calculation. Some candidates referred back to the percentage uncertainty calculated for T and this was not given credit because candidates were asked to use a criterion of 15%.

(e) Some candidates used their second value of q to correctly calculate a value for g and gave an appropriate unit. Common mistakes were to omit a unit or miscalculate the value.

(f) (i) This experiment provided many limitations for discussion. The investigation found how the point of suspension of a triangular card, indicated by length *p*, changed the period of oscillation *T* of the card. Many candidates retreated into familiar ideas about finding the centre of mass of a card or gave general statements such as 'use more accurate apparatus' or a 'mechanical hand' or 'better equipment' which could not be given credit.

Difficulties could be linked to the oscillations. Many candidates recognised a limitation of the experiment was that often the card would only oscillate for a small number of oscillations. Another limitation with the oscillations was that they were often not in one plane. A bald statement such as 'the card was not vertical' or 'the oscillations are affected by wind' on its own did not gain credit; it was the observable consequence of the non-vertical suspension or wind which gained credit.

Many candidates correctly stated difficulties involved in timing to find the period *T* of the oscillations. A bald statement such as 'it was difficult to time' or 'timing a complete oscillation was difficult' or 'oscillations were fast' could not be awarded credit. Some candidates correctly identified that it was difficult to judge the start or end of an oscillation. Many candidates were distracted by the idea that the stop-watch needed to be started at the instant the card was released or focused on the release point, but neither of these ideas gained credit.

(ii) 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 candidates simply stated 'take more readings' as an improvement which on its own did not gain credit; this idea must be linked to plotting a graph.

To improve timing, some candidates suggested using a fiducial marker but this idea only gained credit if the position of the marker was given, e.g. 'placed at the centre of the oscillation'.

The key to this section is for candidates to identify genuine problems associated with setting up this experiment and in obtaining readings. Candidates benefit from identifying limitations during the experiment by thinking about why measurements are difficult to make. 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 their limitations.

PHYSICS

Paper 9702/36
Advanced Practical Skills 2

Key messages

- If a raw value is out of trend to that expected, candidates should be encouraged to check the readings again with the equipment provided in the early stages of data collection.
- In the table work, the number of significant figures in the calculated quantity should relate to the number of significant figures in the raw data with the least number of significant figures. Each calculated quantity should be checked row by row.
- In the graphical work, candidates should be able to read off any points to the nearest half a small square. In particular, candidates should check carefully the read-offs of points used in the gradient calculation and when determining the *y*-intercept.
- When justifying a number of significant figures in a calculated quantity, candidates should relate the number of significant figures in the quantity to the raw readings used in the calculation. Candidates should not use the phrase 'raw readings' without explaining what those readings are, or attempt to use intermediate calculated quantities to justify the number of significant figures.
- To be successful answering **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. General points such as 'measurements were difficult' or 'use more precise measuring instruments' will not usually gain credit without further detail.

General comments

Centres did not generally 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 additional 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.

Many candidates demonstrated good preparation for the practical paper and this was particularly evident in measuring, recording and processing their results.

Nearly all candidates completed the two questions.

Comments on specific questions

Question 1

(a) (i) Most candidates gave the value of M_L as 200 g, showing that they had the correct initial arrangement of the masses.

(ii) Many candidates showed that they were familiar with timing oscillations. A small number of candidates did not understand the meaning of 'period' and recorded a value of 5T or 1/T instead of T, meaning that the value was outside the expected range.

(b) Tables of results were usually clearly presented and nearly all candidates included six sets of readings.

Most column headings included a unit, though this was sometimes missing or incorrect in the $\sqrt{M_L}$ column.

The strongest candidates determined T for a wide range of M_L values. Some Supervisor's reports indicated that the thickness of the slotted masses limited the number that could be placed on the lower nails. For these candidates, a narrower range was accepted. Candidates should be encouraged always to take measurements over the widest range of values available to them with the apparatus.

In most cases the T values were all recorded with 0.1 s precision or all with 0.01 s precision.

Nearly all calculated values of $\sqrt{M_L}$ were correct, although some candidates had not noticed the instruction to record them to three significant figures.

(c) (i) The general standard of graphs was good. Most candidates used simple scales that made good use of the grid, but in a few cases the choice of an awkward scale led to some errors in plotting of points.

Most candidates were given credit for the quality of their results, based on the small scatter about a linear trend.

(ii) A candidate's line of best fit could sometimes be improved by rotation or sideways movement. A single point clearly labelled as anomalous was ignored when judging the fit of the line, but candidates should be reminded that they should not declare more than one point to be anomalous. If more than one point was marked in this way, then the line of best fit was assessed on all points with no allowance for any anomalous points.

(iii) Candidates demonstrated strong skills in determining the gradient and intercept of their lines. The only common mistake was trying to read the intercept value from the T axis when the horizontal axis did not start from zero.

(d) Most candidates compared the graph that they had drawn with the suggested equation and correctly used their gradient and y-intercept values for the constants a and b. Candidates found it more difficult to give correct units. Weaker candidates either did not provide units or the more difficult unit for b ($\mathrm{s\,g^{-1/2}}$) was incorrect.

Question 2

(a) Most candidates recorded a value for the radius of curvature of the block to the nearest mm.

(b) (i) Most candidates measured A and B and correctly calculated their ratio. A few candidates were not awarded credit because they added a unit to the ratio.

(ii) The measurement of d_1 was difficult to make using the apparatus provided. Most candidates were given credit for recording a value to the nearest mm, although many candidates did not record repeated readings.

(iii) The estimation of percentage uncertainty was generally done well. Most candidates recognised that the absolute uncertainty in this measurement was greater than the 1 mm precision of the metre rule.

(iv) Most candidates recorded a d_2 value greater than their d_1 value, as expected.

(c) Most candidates were credited for a second set of values using the lines labelled Q. In a few cases, the d_1 and d_2 values for lines Q were not both smaller than those for lines P.

(d) The calculations for the two k values were carried out well in general.

(e) A large proportion of candidates calculated the percentage difference between the two *k* values. Many went on to compare this difference with the 5% criterion specified in the question, but some chose to use a different criterion (e.g. 20%) and were not awarded credit. Candidates should be reminded to use the given percentage uncertainty when deciding whether or not their values support the relationship.

(f) The calculation of the focal length *f* was carried out successfully by the majority of the candidates.

(g) (i) Most candidates offered four sources of uncertainty, although some found it difficult to describe them clearly. Candidates generally discussed problems with procedures and measurements in the sequence that they occurred in the experiment.

Many candidates said that measuring the radius of the block was difficult as the centre of the block was not marked, but this was not considered serious enough to be awarded credit; the radius could be easily determined by halving the diameter measured along the straight edge.

There were two significant difficulties in the tasks themselves. The first involved achieving the required alignment between the lines seen through the block with those seen from the paper directly. The second was keeping the block in this position while measuring its distance d_1 (or d_2) above the paper.

Difficulty with the alignment was mentioned by a large number of candidates, with some blaming the widening of the lines viewed through the block and going on to suggest drawing thinner lines on the paper as an improvement.

The question stated that a problem with a measurement needed to mention the quantity being measured and the reason for the difficulty. Some candidates missed credit by omitting one or the other of these, for instance 'difficult to measure d_1' without a reason, or 'difficult to hold rule still' without the related quantity.

(ii) Many candidates listed the difficulty of holding the block steadily using their hands, and to solve this problem they proposed clamping the block as an improvement. This was credited if some practical detail of the method was included (e.g. use of a clamp and stand).

The question also stated that an improvement could involve a change in procedure, and several candidates were credited for suggesting that the experiment could be laid out horizontally with the block lying on the bench with the paper and lines vertically behind it.

A few candidates listed problems and improvements that they had seen in mark schemes for experiments from previous papers, but these were often not relevant to the experiment in this paper. Candidates should also note that credit is not given for suggested improvements that could have been carried out in the original experiment e.g. 'repeat readings' or 'view the ruler at right angles'.

PHYSICS

Paper 9702/41
A Level Structured Questions

Key messages

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

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

- Candidates need to 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

In general terms, working was nearly always shown, which is encouraging, but candidates should try to present calculations logically, rather than scattering ideas around the page. The use of English was very good. In addition, it was also encouraging to see many of the definitions were known.

The longer descriptive questions were often found to be difficult and sketching diagrams and graphs also proved to be challenging.

Candidates should always be encouraged to think about the magnitude of the answer they arrive at. For example, the radius of the orbit of a satellite cannot be a few metres, and the number of photons arriving per unit time on a metal surface cannot be of the order 10^{-17}. Checking whether answers appear to be sensible can help to reveal that a mistake has been made.

Comments on specific questions

Question 1

(a) Most candidates had little difficulty in stating the correct formula and in naming the gravitational constant *G*.

(b) A significant number of candidates were able to show the required relationship. However, many candidates did not explain their reasoning by writing that the gravitational force provides the centripetal force. A few candidates made algebraic errors and the π was sometimes not squared.

(c) (i) This calculation was completed well by many candidates. Some candidates did not convert correctly from 24 hours into seconds, and some did not square the period.

(ii) Most candidates were able to state two further conditions for the orbit of a satellite to be geostationary.

Question 2

(a) Many candidates did not understand this question, and gave answers that related to a liquid-in-glass thermometer. Of those who did understand the question, it was common for example to see ‘resistance’ as an answer without an explanation of what resistance was measured.

(b) (i) This was a complicated calculation, but there were many correct answers. Some candidates were not able to use the data correctly and some used temperatures in place of temperature changes. Some candidates made the calculation more complicated than necessary by converting the temperatures into kelvin.

(ii) The point of this question was that the operation of the thermometer leads to an inaccurate reading for the temperature. Candidates did not seem to realise this and almost all suggested changes to improve the precision of the thermometer rather than its accuracy.

(c) (i) This question proved to be challenging. Many candidates were awarded partial credit for realising that the thermometer measured in °C rather than in K.

(ii) Many candidates answered correctly and realised that the substance is an ideal gas.

Question 3

(a) Most candidates were able to state the defining equation for simple harmonic motion. Some candidates were insufficiently precise and described *x* only as displacement, rather than displacement from the equilibrium position.

(b) (i) The majority of the candidates correctly determined the amplitude of the oscillations from the graphs.

(ii) The majority of the candidates showed how to reach the angular frequency of the oscillations.

(iii) There were many correct answers here. The most common misconception was to consider gravitational potential energy alone to find the mass of the object. This ignored the potential energy changes in the spring. Use of the equation for the total energy of simple harmonic oscillations $E = ½M\omega^2 x_0^2$ was the most reliable approach here.

(c) (i) Most candidates gained full credit for stating what is meant by damping.

(ii) Many candidates drew the correct graph here. Some only changed one out of the velocity and the displacement (whereas both will be affected by the presence of damping). Some drew shapes that appeared to be unrelated to the original ellipse provided.

Question 4

(a) Many candidates stated that electric field lines go from positive to negative rather than what the field lines indicate.

(b) (i) The field pattern was drawn well by most candidates. A few candidates had the arrow pointing in the opposite direction and a few drew lines that did not reach the metal plates.

(ii) There were many correct answers here. Weaker candidates sometimes used the formula of the field strength around a point charge, which is incorrect physics in this situation.

(c) (i) Candidates found drawing the path of the proton challenging. Most candidates gained credit for the correct direction of deflection. However, many did not have the proton beginning to deflect near to the point where the region of the electric field began and many did not draw the path as a straight line after leaving the region of the electric field.

(ii) This explanation was challenging. A significant number of candidates correctly stated that the final speed of the helium nucleus is less than the final speed of the proton. However, it was not clear that the candidates realised that the speed was the combination of the constant horizontal velocity and the increasing velocity perpendicular to the plates. Some candidates realised that the charge-to-mass ratio was important in this question but very few candidates separated the velocities into their vertical and horizontal components. A number of candidates thought the helium nucleus was not charged so would not be affected by the electric field at all.

Question 5

(a) (i) Most candidates were able to calculate the charge on the capacitor.

(ii) Most candidates were able to calculate the current in the wire at time $t = 0$. The most common misconception was that the current was 0 because the time was 0.

(iii) The calculation proved to be more challenging than the previous two calculations. A significant number of candidates used the current in place of the capacitance, being unsure of the meaning of the symbol C in $\tau = RC$.

(iv) There were many correct lines sketched here, but some candidates do not realise that an exponential decay curve neither touches the time axis nor becomes horizontal.

(b) (i) This explanation proved to be challenging. Many candidates realised that there was a magnetic field around P due to the current in it. However, the fact that the current was not constant, and that therefore the flux was changing, giving a changing flux in Q and an e.m.f. induced in Q, was often missed. Many candidates went straight to describing an induced current in Q, rather than an induced e.m.f. which then causes an induced current if a circuit is complete.

(ii) Many candidates gained credit.

Question 6

(a) (i) Most candidates correctly identified the faces that were perpendicular to the magnetic field.

(ii) Many candidates knew the electrons would experience a force towards one face and hence an electric field was set up. However, only the stronger candidates realised that the force on the charge carriers (electrons) was perpendicular to both the magnetic field and the current. A misconception evident in responses was that the two fields (electric and magnetic) become equal rather that the forces on the charge carriers due to the two fields becoming equal.

(b) (i) Some candidates were not awarded credit here because they were not specific enough in their responses. The detail of number of charge carriers **per unit volume** and the charge of **a charge carrier** was often missing. Some candidates did not seem familiar with this formula at all and number of moles and time were seen as responses.

(ii) This was generally well answered. However, some candidates answered in terms of *n* rather than *t*, perhaps recalling mark schemes from similar questions from previous examination sessions.

Question 7

(a) (i) A small number of candidates used the r.m.s. potential difference rather than the peak voltage here. However, there were many answers that correctly and clearly showed the maximum power dissipated.

(ii) The most common misconception here was with the shape of the line drawn. The modulus of a sine wave was drawn rather than a $\sin^2$ shape. There were only a few problems with the value of the peak power values and the period of the shape.

(iii) The majority of answers here did not refer to the line but just said that the mean power was half of the peak power. The fact the line was symmetrical about this value was not often known, and candidates who had drawn an incorrect shape of line without the relevant symmetry found it difficult to use their line to answer this question.

(b) (i) Candidates need to make it clear in their answers when one phenomenon causes something else. Here, the vibration of the crystal causing the air to vibrate was often missed.

(ii) Many candidates did not realise that the second crystal would be acting as a receiver. Some stated that the second crystal would vibrate but few went on the add that this would cause an e.m.f. to be generated.

Question 8

(a) Many candidates did not state that the energy was the *photon* energy that was needed to remove the electrons from the surface of the metal.

(b) (i) Many answers here were incorrect due to dividing the maximum kinetic energy of the electrons by the power of the radiation, which produced values that candidates should have realised were not physically realistic.

(ii) There were more correct answers here, but a significant number of candidates used the frequency of the ultraviolet radiation as the threshold frequency and ignored the kinetic energy of the emitted photons.

(c) These two explanations were difficult. Many candidates did not begin with the most fundamental aspect, which was that the photon energy was increased as the frequency of the radiation was increased.

Question 9

(a) Candidates need to remember to include all the detail required in this answer, i.e. the total power of radiation emitted. The word 'total' was often missed, as well as the idea of emission.

(b) (i) There were many correct calculations here. Some candidates tried to use the expression for luminosity, rather than the one for radiant flux intensity.

(ii) There were many correct answers. There were some errors due to caused by not raising the temperature to the power of 4.

(c) The question asked for a method of determining the temperature of the star, so an explanation of the steps taken was required. Most candidates understood that the answer was related to Wien's displacement law, but candidates often did not describe how this is used with a star of known temperature and maximum wavelength and then comparing with the maximum intensity wavelength of the star being measured.

Question 10

(a) (i) Radioactive decay is a nuclear process so candidates need to remember to include the word ‘nucleus’ in their answer.

(ii) Most candidates understood the meaning of ‘spontaneous’.

(b) (i) Most candidates realised that the fluctuations on the line were evidence demonstrating that the decay was random.

(ii) A large majority of candidates drew an appropriate line of best fit.

(iv) Many candidates were unable to take natural logarithms of the exponential decay equation and show that the gradient of the line is $-\lambda$. Some candidates who did the majority of the required work missed out the minus sign.

(iv) There were many correct values of the decay constant. However, some candidates do not understand the labelling of axes on a logarithmic graph and included the factor of 10^{-16} in their calculation. Some weaker candidates attempted to take logarithms of the coordinates.

(c) This explanation proved to be challenging. Many candidates did not realise that there is a fall in mass as it is mass–energy that is conserved and not just mass. They also did not realise that energy was released in the reaction.

PHYSICS

Paper 9702/42
A Level Structured Questions

Key messages

- It is important that candidates use technical language accurately. Examples of words that are often confused by candidates are atom and molecule, nuclide and nucleus, and force and field. Candidates are not able to obtain full credit if they use an inappropriate word that makes the response technically incorrect.
- In defining quantities, candidates need to take care to ensure that the definition they give is dimensionally correct. This often requires use of the phrase 'per unit' where the quantity being defined is the ratio between two other quantities, or 'product' where the quantity being defined is two other quantities being multiplied together.
- Candidates need to 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 had insufficient time in which to complete the paper. There were, however, significant numbers of candidates who did not offer a response to one or more questions. If there is no response, it is never possible for credit to be awarded, so candidates should be encouraged to offer a response to every question on the paper. Even if the candidate is not confident about the answer, it is always possible that the Examiner may be able to award partial credit where there is some response.

Comments on specific questions

Question 1

(a) Only a minority of candidates knew the syllabus 'bookwork' that defines gravitational field as force per unit mass. Many candidates did not give the definition of a quantity but instead answered a different question, asking what is meant by the concept of a gravitational field. As this was such a common misunderstanding of the question, the Examiners did award credit on this occasion for responses that answered the latter question. However, teachers should be aware that candidates are expected to know the syllabus definition that gravitational field is a vector quantity, given by the force per unit mass on an object. Conversely, gravitational field strength is a scalar quantity representing the magnitude of that gravitational field.

(b) (i) This question was generally well answered, and most candidates knew that the gravitational field pattern around a spherical planet is radial and directed towards the centre of the planet.

(ii) This is a good example of a question that candidates need to read carefully to understand what was being asked. Most responses seen were recalled from previous mark schemes relating to past questions that were similar but not the same. This question asked candidates to make reference to their answer in **(b)(i)**. This meant that responses needed to make clear the relevance of the radial field pattern to the motion of the satellite. For full credit, responses needed to consider the direction of the gravitational field, the force this caused on the satellite and the orientation of this force relative to the velocity of the satellite. Most responses seen omitted most of the connections between quantities, and as a consequence it was not a question that was answered well.

(c) (i) This question was generally well answered by candidates who knew that the period of the circular motion of an object at the Equator is 24 hours. Candidates who did not use this as a starting point tended to treat the object at the Equator as a satellite in orbit and were, therefore, unable to be awarded credit.

(ii) Only the most able candidates had an understanding that the two forces acting on the object are the weight of the object downwards and the normal contact force upwards from the Earth's surface. Even some of those who did get this far often had those two forces being equal to each other, leading to a centripetal acceleration of zero. The strongest candidates realised that the contact force is slightly less than the weight, leading to a resultant force towards the centre of the Earth that gives rise to the centripetal acceleration. A large number of weaker candidates again treated the object as a satellite in orbit, and responses that gave the centripetal force as one of the two forces acting (as opposed to understanding this as the resultant force) were very common.

Question 2

(a) Many candidates found it difficult to give definitions that were dimensionally correct, often giving definitions of a quantity that was an energy rather than an energy per unit mass per unit temperature change. Confusion between quantities and units was another common problem for candidates in answering this question.

(b) Many candidates attempted to give answers that were in terms of different letters from the ones defined in the question. In **(i)**, candidates were expected to realise that the work done is zero when there is no net change in volume, and then to apply the first law correctly. In **(ii)**, they were expected to realise that the work done on the system is negative *W*, and then again to apply the first law correctly to an increase in internal energy that was the same as that in **(i)**.

(c) It was expected that candidates would explain that the second temperature increase required a larger amount of thermal energy to produce the same temperature rise, hence leading to a greater specific heat capacity. There was much confusion between thermal energy and internal energy, and the question was not answered well other than by the strongest candidates.

Question 3

(a) The meanings of the terms in the equation were generally well known. Common errors were confusion between number of molecules and amount of substance for *N*, and not being clear that *T* is <u>thermodynamic</u> temperature.

(b) This syllabus derivation was generally well articulated by most candidates.

(c) (i) Candidates who realised they had to equate $\frac{1}{2}mu^2$ with the $(3/2)kT$ expression given in the previous part were generally able to substitute the relevant numbers and then calculate the answer. Some candidates did not realise that the quantity that comes out of this calculation is the r.m.s. speed, and thought they had to also divide by $\sqrt{2}$. Some of the weaker candidates were unable to make a start because they did not realise that the temperature needed to be converted from °C to K.

(ii) This was a higher-level question intended to discriminate between the more able candidates. Candidates were expected to realise that the r.m.s. speed of the molecules depends only on the temperature of the gas, and that the gas remaining in thermal equilibrium with its surroundings meant that the temperature is constant. A variety of interesting curves and lines were seen, but the strongest candidates were able to deduce that the correct line is a horizontal straight line at r.m.s. speed u.

Question 4

(a) (i) Most candidates were able to use the height–time graph to deduce that the amplitude of the oscillations is 8.0 cm.

(ii) This question was also well answered, with most candidates able to apply the period of 4.0 s to the equation for ω.

(iii) This question proved to be more of a challenge to many candidates who were unable to recall correctly the equation for the total energy of an oscillating system. Of those who did know the equation, a variety of mistakes were seen in the calculation, including not squaring the amplitude, forgetting to convert the amplitude into metres, and arithmetic errors due to premature intermediate rounding.

(b) The mark scheme was structured in such a way as to allow most candidates to obtain at least partial credit by getting different aspects of the curve right. Many candidates were able to be awarded full credit.

Question 5

(a) Most candidates could be awarded at least partial credit for this definition.

(b) (i) Whilst there were many candidates who found this question difficult, most realised that they had to read off the value of x at the point where the horizontal straight line ends and the curve begins.

(ii) Most candidates were able to correctly read off a set of values for V and x from the curve and then to substitute these values into the equation for the potential due to a point charge. Comparatively few candidates appreciated that the negative nature of the potential curve meant that the sign of the charge on the sphere must be negative. A common mistake in substituting for the permittivity of free space is to use the data given on the data page for $1/4\pi\varepsilon_0$ but to incorrectly substitute it as the value of $4\pi\varepsilon_0$.

(c) (i) Most candidates realised that they had to use the equation for the potential energy between two point charges from the formula page, but many experienced problems with using it. Common errors were to double, rather than to square, the charge, to use the charge on an electron rather than the charge on the spheres, and to use the radius of the spheres rather than the distance between them. A small number of candidates who did reach the correct numerical answer gave the potential energy as negative, not appreciating that the energy stored between two negative charges must be positive.

(ii) Most candidates found it difficult to give a complete answer to this question. Candidates were expected to draw upon their knowledge of the AS Level part of the syllabus and to realise that, when describing motion, the concepts of displacement, velocity and acceleration need to be considered, and that the concepts of force or energy need to be used to explain them. The mark scheme was structured in such a way as to enable various ways of accessing the credit, but very few candidates attempted to go beyond the fact that the spheres move apart because the force between them is repulsive. Some candidates did not appreciate that 'opposite directions' is not enough to convey the idea of the spheres moving apart because it could equally well mean towards each other.

Question 6

(a) Candidates found it difficult to demonstrate understanding of why the discharge of a capacitor through a resistor is exponential. Most responses were only attempts to describe the shape of the line, often incorrectly as an inverse proportionality relationship. Candidates are expected to appreciate that an exponential relationship occurs when the rate of change of a quantity is proportional to the magnitude of the quantity itself. Within the syllabus, this applies to the rate of decrease of undecayed nuclei in radioactive decay. In the case of a discharging capacitor, the rate of decrease of V is proportional to V because V is proportional to both the charge on the capacitor and the discharge current (rate of decrease of charge) in the resistor. Only the strongest candidates were able to give a complete explanation.

(b) Several different methods for deducing the value of the time constant from the graph were accommodated within the mark scheme. All of the methods were seen in candidate responses, though the most obvious first two methods were the most common. Many candidates were able to answer this question well, and most were at least able to make a start for partial credit.

(c) (i) Most candidates were able to be awarded credit for recall of the defining equation for capacitance. Further credit required accurate read-off from a suitable part of the graphs of a set of values for Q and V, and correctly dealing with two power-of-ten conversions when performing the calculation. Examiners did not consider that a suitable part of the graph to use was the t = 15 s end, where the values of Q and V were so low that the read-offs inevitably involved an uncertainty of at least 10% in each value and therefore led to an answer that was not correct. Despite the many aspects to this marking point that needed to be considered, many candidates were generally able to arrive at the correct answer.

(ii) Many candidates were able to arrive at the correct answer for full credit. The final power-of-ten conversion from Ω to kΩ here proved to be less difficult than the conversions in the previous part.

Question 7

(a) The definition of magnetic flux density was generally well known, though it was not always clear in candidate responses that it is the current in the wire that has to be perpendicular to the magnetic field for the force per unit current per unit length definition not to require inclusion of a sin θ factor. It was often ambiguous what it was that candidates were describing as 'perpendicular', with many responses appearing to be describing the orientation of the force produced rather than the orientation of the current and the magnetic field.

(b) (i) Candidates needed to explain why there is a force, and then to explain why this force is vertical. Candidates were generally more successful in answering the first point than the second point.

(ii) Many candidates were successful in being awarded partial credit. A common error was the omission of the 40 turns factor. Some candidates ignored the instruction to give their answer to three significant figures. Weaker candidates usually started off on the wrong track with responses that were unable to be awarded credit. The most common incorrect starting approach was to equate the magnetic force with the reading on the newton meter rather than the force exerted on the top-pan balance.

(iii) Candidates were expected to deduce (and explain) that, because the balance reading increased, the force on the magnets was downwards and therefore, by Newton's third law, the magnetic force on the coil is upwards. Many of the more able candidates were able to deduce correctly the new reading of 0.542 N, but only the strongest candidates successfully explained their reasoning.

Question 8

(a) Candidates who knew their 'bookwork' were generally aware that Lenz's law governs the direction of the induced e.m.f. and were able to articulate the law correctly.

(b) (i) This was generally well answered, with a significant proportion of candidates achieving full credit.

(ii) Most candidates realised that the variation of V_2 with t is sinusoidal with a period of 0.040 s. Many correctly calculated the peak voltage of 6.5 V and represented that consistently in their responses. Candidates found it more difficult to deduce the correct phase for the voltage, with all but the strongest candidates usually giving answers that were either in phase or in antiphase with Fig. 8.2.

(iii) Most creditworthy attempts to explain the variation of V_2 with t got as far as a statement of Faraday's law of electromagnetic induction and then stopped. Candidates needed to articulate how the laws of electromagnetic induction applied to this situation, and only the strongest candidates were successful at doing this.

Question 9

(a) (i) This was another question where many candidates answered a different question from that which was asked. There were many responses that gave answers to questions asking either for a description of the appearance of an emission spectrum or for an explanation of how an emission spectrum is formed, but where candidates did not make a connection between the emission spectrum and the idea of discrete energy levels. There was much confusion between the concepts of photon energy, energy transitions and energy levels, with many responses lacking accuracy in the way these technical terms were used.

(ii) There were many good attempts at this question, with a significant minority of candidates achieving full credit. Those who did identify the correct starting equation and the correct wavelength of the line that corresponds to the transition from level X to the –3.400 eV energy level were usually able to be awarded partial credit, but some candidates were a little confused with working that led to a positive value for the energy of level X. Weaker candidates generally found themselves unable to make a start, with many random attempts to add and subtract the other energy levels to somehow arrive at a value for X.

(b) (i) This question was well answered by most candidates.

(ii) Many candidates correctly identified that the observation shows that the galaxy is moving away from the observer. There was much confusion among weaker candidates between what the observation shows about this galaxy and the extension of such observations into the expansion of the Universe and the Big Bang theory. In particular, the term 'galaxy' was often used incorrectly as if it referred to the 'Universe', with many candidates suggesting that the observation shows that the 'galaxy is expanding'.

(iii) This calculation was well answered by a large proportion of candidates, and many candidates were awarded full credit.

(c) This is another question that was well answered by many candidates. Most candidates who knew the equation for the Hubble constant were usually able to achieve full credit by the error-carried-forward principle even if their answer to **(b)(iii)** was incorrect.

Question 10

(a) (i) The use of a β^+-emitting tracer was generally well known by candidates, and most candidates were able to articulate it well enough to be awarded at least partial credit.

(ii) This was another well-answered question, with the pair annihilation of the positron with an electron being familiar to most candidates. Candidates did not always make clear that pair annihilation involves the conversion of the whole mass of the positron and electron into the energy of the gamma photons.

(b) The more able candidates were usually able to correctly use $E = mc^2$ and $E = hc/\lambda$ to demonstrate the calculation of the 2.4 pm wavelength value. Often missing from responses was an explanation that the masses of the two particles involved become the energy of two gamma photons. Another common error was to use the de Broglie wavelength equation as a starting point, and to calculate momentums of electrons apparently travelling at the speed of light.

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

In general terms, working was nearly always shown, which is encouraging, but candidates should try to present calculations logically, rather than scattering ideas around the page. The use of English was very good. In addition, it was also encouraging to see many of the definitions were known.

The longer descriptive questions were often found to be difficult and sketching diagrams and graphs also proved to be challenging.

Candidates should always be encouraged to think about the magnitude of the answer they arrive at. For example, the radius of the orbit of a satellite cannot be a few metres, and the number of photons arriving per unit time on a metal surface cannot be of the order 10^{-17}. Checking whether answers appear to be sensible can help to reveal that a mistake has been made.

Comments on specific questions

Question 1

(a) Most candidates had little difficulty in stating the correct formula and in naming the gravitational constant *G*.

(b) A significant number of candidates were able to show the required relationship. However, many candidates did not explain their reasoning by writing that the gravitational force provides the centripetal force. A few candidates made algebraic errors and the π was sometimes not squared.

(c) (i) This calculation was completed well by many candidates. Some candidates did not convert correctly from 24 hours into seconds, and some did not square the period.

(ii) Most candidates were able to state two further conditions for the orbit of a satellite to be geostationary.

Question 2

(a) Many candidates did not understand this question, and gave answers that related to a liquid-in-glass thermometer. Of those who did understand the question, it was common for example to see 'resistance' as an answer without an explanation of what resistance was measured.

(b) (i) This was a complicated calculation, but there were many correct answers. Some candidates were not able to use the data correctly and some used temperatures in place of temperature changes. Some candidates made the calculation more complicated than necessary by converting the temperatures into kelvin.

(ii) The point of this question was that the operation of the thermometer leads to an inaccurate reading for the temperature. Candidates did not seem to realise this and almost all suggested changes to improve the precision of the thermometer rather than its accuracy.

(c) (i) This question proved to be challenging. Many candidates were awarded partial credit for realising that the thermometer measured in °C rather than in K.

(ii) Many candidates answered correctly and realised that the substance is an ideal gas.

Question 3

(a) Most candidates were able to state the defining equation for simple harmonic motion. Some candidates were insufficiently precise and described *x* only as displacement, rather than displacement from the equilibrium position.

(b) (i) The majority of the candidates correctly determined the amplitude of the oscillations from the graphs.

(ii) The majority of the candidates showed how to reach the angular frequency of the oscillations.

(iii) There were many correct answers here. The most common misconception was to consider gravitational potential energy alone to find the mass of the object. This ignored the potential energy changes in the spring. Use of the equation for the total energy of simple harmonic oscillations $E = ½M\omega^2 x_0^2$ was the most reliable approach here.

(c) (i) Most candidates gained full credit for stating what is meant by damping.

(ii) Many candidates drew the correct graph here. Some only changed one out of the velocity and the displacement (whereas both will be affected by the presence of damping). Some drew shapes that appeared to be unrelated to the original ellipse provided.

Question 4

(a) Many candidates stated that electric field lines go from positive to negative rather than what the field lines indicate.

(b) (i) The field pattern was drawn well by most candidates. A few candidates had the arrow pointing in the opposite direction and a few drew lines that did not reach the metal plates.

(ii) There were many correct answers here. Weaker candidates sometimes used the formula of the field strength around a point charge, which is incorrect physics in this situation.

(c) (i) Candidates found drawing the path of the proton challenging. Most candidates gained credit for the correct direction of deflection. However, many did not have the proton beginning to deflect near to the point where the region of the electric field began and many did not draw the path as a straight line after leaving the region of the electric field.

(ii) This explanation was challenging. A significant number of candidates correctly stated that the final speed of the helium nucleus is less than the final speed of the proton. However, it was not clear that the candidates realised that the speed was the combination of the constant horizontal velocity and the increasing velocity perpendicular to the plates. Some candidates realised that the charge-to-mass ratio was important in this question but very few candidates separated the velocities into their vertical and horizontal components. A number of candidates thought the helium nucleus was not charged so would not be affected by the electric field at all.

Question 5

(a) (i) Most candidates were able to calculate the charge on the capacitor.

(ii) Most candidates were able to calculate the current in the wire at time $t = 0$. The most common misconception was that the current was 0 because the time was 0.

(iii) The calculation proved to be more challenging than the previous two calculations. A significant number of candidates used the current in place of the capacitance, being unsure of the meaning of the symbol C in $\tau = RC$.

(iv) There were many correct lines sketched here, but some candidates do not realise that an exponential decay curve neither touches the time axis nor becomes horizontal.

(b) (i) This explanation proved to be challenging. Many candidates realised that there was a magnetic field around P due to the current in it. However, the fact that the current was not constant, and that therefore the flux was changing, giving a changing flux in Q and an e.m.f. induced in Q, was often missed. Many candidates went straight to describing an induced current in Q, rather than an induced e.m.f. which then causes an induced current if a circuit is complete.

(ii) Many candidates gained credit.

Question 6

(a) (i) Most candidates correctly identified the faces that were perpendicular to the magnetic field.

(ii) Many candidates knew the electrons would experience a force towards one face and hence an electric field was set up. However, only the stronger candidates realised that the force on the charge carriers (electrons) was perpendicular to both the magnetic field and the current. A misconception evident in responses was that the two fields (electric and magnetic) become equal rather that the forces on the charge carriers due to the two fields becoming equal.

(b) (i) Some candidates were not awarded credit here because they were not specific enough in their responses. The detail of number of charge carriers **per unit volume** and the charge of **a charge carrier** was often missing. Some candidates did not seem familiar with this formula at all and number of moles and time were seen as responses.

(ii) This was generally well answered. However, some candidates answered in terms of *n* rather than *t*, perhaps recalling mark schemes from similar questions from previous examination sessions.

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(a) (i) A small number of candidates used the r.m.s. potential difference rather than the peak voltage here. However, there were many answers that correctly and clearly showed the maximum power dissipated.

(ii) The most common misconception here was with the shape of the line drawn. The modulus of a sine wave was drawn rather than a $\sin^2$ shape. There were only a few problems with the value of the peak power values and the period of the shape.

(iii) The majority of answers here did not refer to the line but just said that the mean power was half of the peak power. The fact the line was symmetrical about this value was not often known, and candidates who had drawn an incorrect shape of line without the relevant symmetry found it difficult to use their line to answer this question.

(b) (i) Candidates need to make it clear in their answers when one phenomenon causes something else. Here, the vibration of the crystal causing the air to vibrate was often missed.

(ii) Many candidates did not realise that the second crystal would be acting as a receiver. Some stated that the second crystal would vibrate but few went on the add that this would cause an e.m.f. to be generated.

Question 8

(a) Many candidates did not state that the energy was the *photon* energy that was needed to remove the electrons from the surface of the metal.

(b) (i) Many answers here were incorrect due to dividing the maximum kinetic energy of the electrons by the power of the radiation, which produced values that candidates should have realised were not physically realistic.

(ii) There were more correct answers here, but a significant number of candidates used the frequency of the ultraviolet radiation as the threshold frequency and ignored the kinetic energy of the emitted photons.

(c) These two explanations were difficult. Many candidates did not begin with the most fundamental aspect, which was that the photon energy was increased as the frequency of the radiation was increased.

Question 9

(a) Candidates need to remember to include all the detail required in this answer, i.e. the total power of radiation emitted. The word ‘total’ was often missed, as well as the idea of emission.

(b) (i) There were many correct calculations here. Some candidates tried to use the expression for luminosity, rather than the one for radiant flux intensity.

(ii) There were many correct answers. There were some errors due to caused by not raising the temperature to the power of 4.

(c) The question asked for a method of determining the temperature of the star, so an explanation of the steps taken was required. Most candidates understood that the answer was related to Wien’s displacement law, but candidates often did not describe how this is used with a star of known temperature and maximum wavelength and then comparing with the maximum intensity wavelength of the star being measured.

Question 10

(a) (i) Radioactive decay is a nuclear process so candidates need to remember to include the word 'nucleus' in their answer.

(ii) Most candidates understood the meaning of 'spontaneous'.

(b) (i) Most candidates realised that the fluctuations on the line were evidence demonstrating that the decay was random.

(ii) A large majority of candidates drew an appropriate line of best fit.

(iv) Many candidates were unable to take natural logarithms of the exponential decay equation and show that the gradient of the line is $-\lambda$. Some candidates who did the majority of the required work missed out the minus sign.

(iv) There were many correct values of the decay constant. However, some candidates do not understand the labelling of axes on a logarithmic graph and included the factor of 10^{-16} in their calculation. Some weaker candidates attempted to take logarithms of the coordinates.

(c) This explanation proved to be challenging. Many candidates did not realise that there is a fall in mass as it is mass–energy that is conserved and not just mass. They also did not realise that energy was released in the reaction.

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.
- The numerical answers towards the end of **Question 2** require candidates to show all their working and for the values to be correctly evaluated with appropriate units. A full understanding of significant figures and the treatment of uncertainties is required.
- Candidates need to understand how to use logarithms (both to base ten and natural) correctly.
- 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 that did not show a workable experiment. In the analysis section, candidates must explicitly state the quantities to be plotted on each axis. It is essential for candidates to have experienced practical work in preparation for answering this question.

In **Question 2**, candidates should be familiar with completing a results table for quantities and their uncertainty, and with finding the gradient and *y*-intercept of a graph. For some 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.

In question parts requiring mathematical manipulation, stronger candidates clearly stated the equation used with correct substitution of numbers, and then calculated the answer and unit. Candidates should be encouraged to 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

Most candidates correctly identified the independent and dependent variables. Candidates should then consider the control of variables and should explicitly state the quantities that need to be kept constant to make the experiment a fair test. In this experiment it was expected that candidates would state that t (thickness of the copper sheet) and B (magnetic flux density) would be kept constant. When referring to B, credit was not given for 'magnetic field' since it was not a quantity. Credit was also given for stating that the distance between the magnets/coils and the copper sheet should be kept constant. Similarly, credit was given for stating that s_0 (initial displacement of the copper sheet) needed to be kept constant. Some stronger candidates gained further credit by explaining a method to keep the initial displacement constant using a mark and moving the copper sheet to the mark each time. An explanation was needed – credit was not given for the statement 'use a fiducial mark' on its own.

Candidates were awarded credit for a clearly labelled diagram. Diagrams should be drawn of the workable experiment. Stronger candidates suggested placing a thin rod (e.g. nail) through the hole of the copper sheet and supporting the rod in a clamp and stand on a bench.

Many candidates suggested the use of a rule or ruler to measure the horizontal distance *s* after five oscillations. Some of these candidates did not gain credit for this measurement because the rule or ruler was not shown clamped in the correct orientation in the diagram. To gain credit for this measurement, additional detail on the method used to measure *s* accurately was required. Because the sheet is in motion when the measurement is taken, the oscillation should be recorded using a video camera and *s* measured through a frame-by-frame playback with the rule or ruler in the frame.

Candidates did not gain credit for the vague statement 'use a ruler to measure area' – candidates needed to explicitly state that the length and width of the copper sheet needed to be measured either with a ruler or calipers and that the area was equal to the length × width.

Most candidates stated that a micrometer (or calipers) would be used to measure the thickness *t* of the sheet. Candidates who stated using a 'ruler or micrometer' did not gain credit – candidates should be explicit in the measuring instruments used.

Most candidates stated that they would use a Hall probe to determine the magnetic flux density *B*. Stronger candidates stated that the probe would be rotated until a maximum was detected. Many stronger candidates stated that the magnetic flux density would be measured first in one direction and then the probe would be rotated in the opposite (180°) direction, and the magnetic flux density measurement would be repeated and the average determined.

Many candidates suggested correct axes for a graph (often ln *s* against *A* or *A* against ln *s*). A significant number of candidates incorrectly suggested plotting *s* against *A*. 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. Some candidates correctly determined the logarithmic format of the equation but then incorrectly suggested plotting *s* against *A*. Candidates also 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. Some candidates incorrectly stated that the straight line must pass through the origin. Stronger candidates often indicated that the straight line would pass through a *y*-intercept and quoted the expression for the *y*-intercept.

Candidates needed to explain how they would determine the value of *K* from the experimental results using the gradient. Some candidates correctly identified a relationship between *K* and the gradient but did not make *K* the subject of the equation.

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.

When describing safety precautions, candidates should be encouraged to explain how the precaution proposed is relevant to the experiment. Relevant precautions that prevented damage from the sheet falling or cuts from the sharp edges of the sheet gained credit.

There was credit available for the additional detail of repeating the experiment for each value of *A* and determining an average for *s*. The candidates who gained credit here made it clear that the area *A* of the sheet remained constant when the measurement of *s* was repeated.

Question 2

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

(b) Most candidates were able to calculate values of $1/R$ correctly. Since R was recorded to two significant figures, values of $1/R$ should have been recorded to two (or three) significant figures. Care should be taken when rounding as this sometimes leads to errors.

Most candidates determined the absolute uncertainty in $1/R$ correctly.

(c) (i) The points and error bars were straightforward to plot. When plotting points, 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. For example, the third plot was often ± 1.3 which meant that the total length of the error bar should be 5.2 small squares not 6 small squares.

(ii) Most candidates appear to be using a sharp pencil and a transparent 30 cm ruler. For correctly plotted data, the line of best fit did not pass through both the highest and lowest point. The worst acceptable line was drawn well in general, and many stronger candidates drew a line that passed through all the error bars. Candidates should clearly label the lines drawn. Where a dashed line represents 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 on the line of best fit that are easy to read, i.e. points that are on grid lines.

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 and an appropriate subtraction.

(d) Most candidates correctly determined the average diameter d but many did not determine the absolute uncertainty in d (± 0.003 mm) correctly. From repeated values of the same quantity, the absolute uncertainty should be determined by finding half the range.

(e) (i) Most candidates correctly used the gradient to determine ρ. A common error was to use an incorrect power of ten, usually from an incorrect conversion from the gradient e.g. a gradient value of 1.80 should be converted to 18.0 Ω m or 1800 Ω cm leading to a ρ value of 1.44×10^{-6} Ω m or 1.44×10^{-4} Ω cm. Stronger candidates clearly demonstrated the method used. It was expected that ρ would be given to two or three significant figures.

(ii) Many candidates correctly multiplied the percentage uncertainty in d by 2 and added it to the percentage uncertainty in the two resistances and the percentage uncertainty in the gradient. Again, stronger candidates clearly indicated the method used. Some candidates gained credit for a correct use of a maximum or minimum method with full working shown.

(f) Many candidates correctly calculated a value for R. Stronger candidates realised that R = gradient / 0.95. Credit was also given to those who correctly calculated R by substitution into the original equation. Correct substitution of numbers was essential for credit.

The absolute uncertainty in R was easier for those candidates who realised that R = gradient / 0.95, therefore only needing to use the percentage uncertainty in the gradient to calculate the uncertainty in R. The alternative method for those who used the original formula required the use of the fractional uncertainty in d (multiplied by 2), the two resistances and ρ to calculate the uncertainty in R.

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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.
- The numerical answers towards the end of **Question 2** require candidates to show all their working and for the values to be correctly evaluated with appropriate units. A full understanding of significant figures and the treatment of uncertainties is required.
- Candidates need to understand how to use logarithms (both to base ten and natural) correctly.
- 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 that did not show a workable experiment. In the analysis section, candidates must explicitly state the quantities to be plotted on each axis. It is essential for candidates to have experienced practical work in preparation for answering this question.

In **Question 2**, candidates should be familiar with completing a results table for quantities and their uncertainty, and with finding the gradient and *y*-intercept of a graph. For some 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.

In question parts requiring mathematical manipulation, stronger candidates clearly stated the equation used with correct substitution of numbers, and then calculated the answer and unit. Candidates should be encouraged to 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

Most candidates correctly identified the independent and dependent variables. Candidates should then consider the control of variables and should explicitly state the quantities that need to be kept constant to make the experiment a fair test. In this experiment it was expected that candidates would state that A (area of the copper sheer) and B (magnetic flux density) would be kept constant. When referring to B, credit was not given for 'magnetic field' since it was not a quantity. Credit was also given for stating that the distance between the magnets/coils and the copper sheet should be kept constant. Similarly, credit was given for stating that the initial displacement of the copper sheet needed to be kept constant. Some stronger candidates gained further credit by explaining a method to keep the initial displacement constant using a mark and moving the copper sheet to the mark each time. An explanation was needed – credit could not be given for the statement 'use a fiducial mark' on its own.

Candidates were awarded credit for a clearly labelled diagram. Diagrams should be drawn of the workable experiment. Stronger candidates explained that they would place a thin rod (e.g. nail) through the hole of the copper sheet and then support the rod in a clamp and stand on a bench.

Many candidates suggested using a stop-watch to measure the time t from when the sheet was released until it became stationary. Some candidates did not gain credit because they stated that they would wait for the oscillations to become steady before starting the stop-watch or that they would stop the stop-watch after n oscillations. Some weaker candidates suggested using a stop-watch for measuring time without explaining which time was being measured. This was considered vague and did not gain credit.

Most candidates stated that a micrometer (or calipers) would be used to measure the thickness z of the sheet. Candidates who stated using a 'ruler or micrometer' did not gain credit – candidates should be explicit in the measuring instruments used.

Candidates did not gain credit for the vague statement 'use a ruler to measure area' – candidates needed to explicitly state that the length and width of the copper sheet needed to be measured either with a ruler or calipers and that the area was equal to the length $\times$ width.

Most candidates stated that they would use a Hall probe to determine the magnetic flux density B. Stronger candidates stated that the probe would be rotated until a maximum was detected. Many of these stronger candidates stated that the magnetic flux density would be measured first in one direction and then the probe would be rotated in the opposite (180°) direction, and the magnetic flux density measurement would be repeated and the average determined.

Many candidates suggested correct axes for a graph (often lg t against lg z or ln t against ln z). A significant number of candidates incorrectly suggested plotting t against z. 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. Some candidates correctly determined the logarithmic format of the equation but then incorrectly suggested plotting t against z. Candidates also 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. Several candidates incorrectly stated that the straight line must pass through the origin. Stronger candidates often indicated that the straight line would pass through a y-intercept and quoted the expression for the y-intercept.

Candidates needed to explain how they would determine values of K and q from the experimental results using the gradient and y-intercept. Many candidates correctly identified that q was equal to the gradient. An explicit statement was needed – it was not acceptable to say 'use the gradient to find q and the y-intercept to find K'.

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.

When describing safety precautions, candidates should be encouraged to explain how the precaution proposed is relevant to the experiment. In this experiment, relevant precautions that prevented damage from the sheet falling or cuts from the sharp edges gained credit.

There was credit for suggesting repeating the experiment for each value of z and determining an average for t. The candidates who gained credit here made it clear that the thickness z of the sheet remained constant when the measurement of t was repeated. Credit was also given for a method to determine the density of the sheet. Candidates needed to describe measuring the mass using a top-pan balance, show how the volume would be determined ($A \times z$) and state the equation used to obtain the density.

Question 2

(a) Candidates who were mathematically confident were able to work through the algebra and achieve credit. Candidates should use the white space on the question paper to rearrange the equation into an equation of a straight line. Some candidates incorrectly omitted the negative sign from the y-intercept. Candidates should be encouraged to simplify expressions, e.g. $2c/4h$ should be written as $c/2h$.

(b) Most candidates were able to calculate values of *T* correctly, although a number of candidates incorrectly wrote in the last value 0.88 as 0.9. Since *d* was recorded to two significant figures, values of *T* and *f* should have been recorded to two (or three) significant figures. A common error was recording the last value of *f* as 1136. Care should be taken when rounding as this sometimes leads to errors.

Many candidates did not determine the absolute uncertainty in *T* or *f* correctly.

(c) (i) The points and error bars were straightforward to plot. When plotting points, 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. For example, the fifth plot was often ± 83 which meant that the total length of the error bar should be 16.6 small squares not 16 squares.

(ii) Most candidates appear to be using a sharp pencil and a transparent 30 cm ruler. For correctly plotted data, the line of best fit did not pass through both the highest and lowest point. The worst acceptable line was drawn well in general, and many stronger candidates drew a line that passed through all the error bars. Candidates should clearly label the lines drawn. Where a dashed line represents 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 on the line of best fit that are easy to read, i.e. points that are on grid lines.

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 and an appropriate subtraction.

(d) Most candidates correctly determined the average height *h* but many did not determine the absolute uncertainty in *h* (± 0.3 cm) correctly. From repeated values of the same quantity, the absolute uncertainty should be determined by finding half the range.

(e) (i) Most candidates correctly used the gradient to determine *c*. Common errors were either in using too many significant figures or an incorrect power of ten in the unit e.g. 34 000 m s^{-1} rather than 340 m s^{-1} or 34 000 cm s^{-1}. Stronger candidates clearly demonstrated the method used.

(ii) Most candidates correctly added the percentage uncertainty in *h* to the percentage uncertainty in the gradient. Again, stronger candidates clearly indicated the method used. Some candidates gained credit for the use of a maximum or minimum method with full working shown.

(f) Many candidates correctly calculated a value for *h*. Correct substitution of numbers was essential for credit. A common error was not calculating the (2*n* – 1) part of the expression correctly.

The absolute uncertainty in *h* was challenging. Many candidates worked out the fractional uncertainty. Other candidates used maximum and minimum methods but either used a maximum value of *c* divided by the maximum value of *f* or did not use the maximum or minimum value of *c*.

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.
- The numerical answers towards the end of **Question 2** require candidates to show all their working and for the values to be correctly evaluated with appropriate units. A full understanding of significant figures and the treatment of uncertainties is required.
- Candidates need to understand how to use logarithms (both to base ten and natural) correctly.
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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 that did not show a workable experiment. In the analysis section, candidates must explicitly state the quantities to be plotted on each axis. It is essential for candidates to have experienced practical work in preparation for answering this question.

In **Question 2**, candidates should be familiar with completing a results table for quantities and their uncertainty, and with finding the gradient and *y*-intercept of a graph. For some 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.

In question parts requiring mathematical manipulation, stronger candidates clearly stated the equation used with correct substitution of numbers, and then calculated the answer and unit. Candidates should be encouraged to 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

Most candidates correctly identified the independent and dependent variables. Candidates should then consider the control of variables and should explicitly state the quantities that need to be kept constant to make the experiment a fair test. In this experiment it was expected that candidates would state that t (thickness of the copper sheet) and B (magnetic flux density) would be kept constant. When referring to B, credit was not given for 'magnetic field' since it was not a quantity. Credit was also given for stating that the distance between the magnets/coils and the copper sheet should be kept constant. Similarly, credit was given for stating that s_0 (initial displacement of the copper sheet) needed to be kept constant. Some stronger candidates gained further credit by explaining a method to keep the initial displacement constant using a mark and moving the copper sheet to the mark each time. An explanation was needed – credit was not given for the statement 'use a fiducial mark' on its own.

Candidates were awarded credit for a clearly labelled diagram. Diagrams should be drawn of the workable experiment. Stronger candidates suggested placing a thin rod (e.g. nail) through the hole of the copper sheet and supporting the rod in a clamp and stand on a bench.

Many candidates suggested the use of a rule or ruler to measure the horizontal distance *s* after five oscillations. Some of these candidates did not gain credit for this measurement because the rule or ruler was not shown clamped in the correct orientation in the diagram. To gain credit for this measurement, additional detail on the method used to measure *s* accurately was required. Because the sheet is in motion when the measurement is taken, the oscillation should be recorded using a video camera and *s* measured through a frame-by-frame playback with the rule or ruler in the frame.

Candidates did not gain credit for the vague statement 'use a ruler to measure area' – candidates needed to explicitly state that the length and width of the copper sheet needed to be measured either with a ruler or calipers and that the area was equal to the length × width.

Most candidates stated that a micrometer (or calipers) would be used to measure the thickness *t* of the sheet. Candidates who stated using a 'ruler or micrometer' did not gain credit – candidates should be explicit in the measuring instruments used.

Most candidates stated that they would use a Hall probe to determine the magnetic flux density *B*. Stronger candidates stated that the probe would be rotated until a maximum was detected. Many stronger candidates stated that the magnetic flux density would be measured first in one direction and then the probe would be rotated in the opposite (180°) direction, and the magnetic flux density measurement would be repeated and the average determined.

Many candidates suggested correct axes for a graph (often ln *s* against *A* or *A* against ln *s*). A significant number of candidates incorrectly suggested plotting *s* against *A*. 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. Some candidates correctly determined the logarithmic format of the equation but then incorrectly suggested plotting *s* against *A*. Candidates also 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. Some candidates incorrectly stated that the straight line must pass through the origin. Stronger candidates often indicated that the straight line would pass through a *y*-intercept and quoted the expression for the *y*-intercept.

Candidates needed to explain how they would determine the value of *K* from the experimental results using the gradient. Some candidates correctly identified a relationship between *K* and the gradient but did not make *K* the subject of the equation.

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.

When describing safety precautions, candidates should be encouraged to explain how the precaution proposed is relevant to the experiment. Relevant precautions that prevented damage from the sheet falling or cuts from the sharp edges of the sheet gained credit.

There was credit available for the additional detail of repeating the experiment for each value of *A* and determining an average for *s*. The candidates who gained credit here made it clear that the area *A* of the sheet remained constant when the measurement of *s* was repeated.

Question 2

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

(b) Most candidates were able to calculate values of $1/R$ correctly. Since R was recorded to two significant figures, values of $1/R$ should have been recorded to two (or three) significant figures. Care should be taken when rounding as this sometimes leads to errors.

Most candidates determined the absolute uncertainty in $1/R$ correctly.

(c) (i) The points and error bars were straightforward to plot. When plotting points, 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. For example, the third plot was often ± 1.3 which meant that the total length of the error bar should be 5.2 small squares not 6 small squares.

(ii) Most candidates appear to be using a sharp pencil and a transparent 30 cm ruler. For correctly plotted data, the line of best fit did not pass through both the highest and lowest point. The worst acceptable line was drawn well in general, and many stronger candidates drew a line that passed through all the error bars. Candidates should clearly label the lines drawn. Where a dashed line represents 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 on the line of best fit that are easy to read, i.e. points that are on grid lines.

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 and an appropriate subtraction.

(d) Most candidates correctly determined the average diameter d but many did not determine the absolute uncertainty in d (± 0.003 mm) correctly. From repeated values of the same quantity, the absolute uncertainty should be determined by finding half the range.

(e) (i) Most candidates correctly used the gradient to determine ρ. A common error was to use an incorrect power of ten, usually from an incorrect conversion from the gradient e.g. a gradient value of 1.80 should be converted to 18.0 Ω m or 1800 Ω cm leading to a ρ value of 1.44×10^{-6} Ω m or 1.44×10^{-4} Ω cm. Stronger candidates clearly demonstrated the method used. It was expected that ρ would be given to two or three significant figures.

(ii) Many candidates correctly multiplied the percentage uncertainty in d by 2 and added it to the percentage uncertainty in the two resistances and the percentage uncertainty in the gradient. Again, stronger candidates clearly indicated the method used. Some candidates gained credit for a correct use of a maximum or minimum method with full working shown.

(f) Many candidates correctly calculated a value for R. Stronger candidates realised that R = gradient / 0.95. Credit was also given to those who correctly calculated R by substitution into the original equation. Correct substitution of numbers was essential for credit.

The absolute uncertainty in R was easier for those candidates who realised that R = gradient / 0.95, therefore only needing to use the percentage uncertainty in the gradient to calculate the uncertainty in R. The alternative method for those who used the original formula required the use of the fractional uncertainty in d (multiplied by 2), the two resistances and ρ to calculate the uncertainty in R.