PHYSICS

Paper 9702/12
Multiple Choice

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

General comments

It is advisable to reads through each question in its entirety before looking at the four possible answers. When answering numerical questions, candidates should take particular care with prefixes and powers-of-ten, and it is a good idea to double-check any calculations performed on a calculator. The spaces on the question paper should be used to carry out the calculations and any other necessary working such as rearranging equations.

Questions involving graphs need careful attention, taking note of which quantities are plotted on which axes, as these may differ from the 'standard' graphs in some text books.

Candidates found **Questions 4**, **8**, **13**, **18** and **20** difficult. They found **Questions 2**, **3**, **15**, **24**, **27**, **30**, **34** and **40** relatively easy.

Comments on specific questions

Question 1

The majority of candidates chose the correct answer **C**, though several selected answer **A**, the mass of a coin. A mass of 10^{-4} kg is 0.1 g; the mass of a small coin (e.g. a British 5p piece) is approximately 3 g.

Question 4

Several candidates found this question difficult, with many choosing answer **A** or **B** rather than the correct answer **C**. The time between the two pulses displayed on the CRO is the time for the pulse to travel from the transmitter to the receiver and back again –12.6 μs. As there are three squares between the two pulses on the screen, the time-base setting must be $\frac{12.6}{3} = 4.2\,\mu s\,cm^{-1}$.

Question 5

The majority of candidates answered this question correctly (answer **D**), though some candidates calculated the uncertainty by *subtracting* the uncertainty in the first cylinder from the uncertainty in the second cylinder (answer **A**), rather than adding them together.

Question 7

Just over half the candidates answered this question correctly (answer **A**), with the majority of the other candidates selecting answer **B**. One way of approaching this question is to apply the equation $s = ut + \frac{1}{2}at^2$ between the first oil drop and the second oil drop, and then between the first oil drop and the third oil drop. If the velocity of the car is u when the first drop of oil leaks from the car:

$$9.0 = u \times 2 + \frac{1}{2}a \times 2^2 = 2u + 2a \quad (1)$$

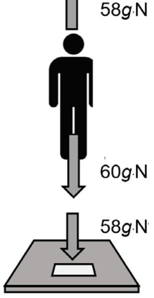
$$21 = u \times 4 + \frac{1}{2}a \times 4^2 = 4u + 8a \quad (2)$$

Eqn (2) – 2 × eqn (1) gives: $3 = 4a \Rightarrow a = 0.75\,m\,s^{-2}$

Alternatively, the average speed between the first two oil drops is $4.5\,m\,s^{-1}$, which increases to an average speed of $6.0\,m\,s^{-1}$ between the second and third oil drops in the next two seconds, i.e. an acceleration of $1.5\,m\,s^{-1}$ in
2 seconds, or $0.75\,m\,s^{-2}$.

Question 8

The majority of candidates found this question difficult, with roughly equal numbers of candidates choosing each option. The reading on the bathroom scales is 58 kg, so the downward force exerted on the bathroom scales must be 58 *g*N. The upward force exerted by the scales on the person must also be 58 *g*N. The weight of the person is 60 *g*N acting downwards, so the resultant force is 2 *g*N acting downwards, implying that the person must be either accelerating or decelerating.



If the person is moving downwards the person will be speeding up, but if the person is moving upwards, the person will be slowing down. Only answer **D** is a possible motion of the person.

Question 10

The majority of candidates answered this question correctly (answer **B**), though significant numbers of candidates chose either answer **A** or **C**. Although linear momentum is conserved in statement **A**, half the kinetic energy is lost, so the statement cannot be true. In statement **C**, neither linear momentum nor kinetic energy are conserved.

Question 12

Approximately half the candidates answered this question correctly (answer **A**). Many of the rest ignored the weight of the rod in their calculations (answer **C**).

Question 13

The question asks for the directions of the forces such that the block is in equilibrium i.e. neither translating nor rotating. Many candidates chose option **D**, probably because the lengths of the three forces cancel out, but there will still be rotation. Taking moments about the point in option **A**, where the vertical and horizontal forces cross, shows there is a (clockwise) moment acting on the block. In **C**, although the three forces are concurrent, there is a resultant force in both the *x* and *y* directions.

Question 14

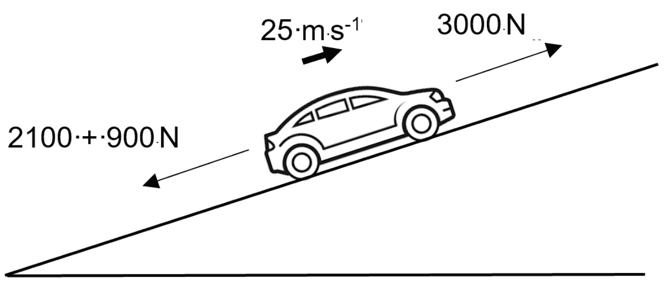
Candidates found this quite difficult. Some only calculated the *change* in volume of the gas (0.0040 m^3 – answer **A**); others *added* the change in volume of the gas to its initial volume (0.0160 m^3 – answer **C**). As work is being done *on* the gas, the gas must be being compressed. The correct answer is the initial volume of the gas minus the change in volume ($0.012 - \frac{400}{1.0 \times 10^5} = 0.0080\,m^3$ – answer **B**).

Question 16

The majority of the candidates answered this question correctly (answer **D**), though a significant number of candidates chose answer **A** as the stage when most work is done on the sledge. When the sledge is being carried back 20 m at constant speed there is no work being done on the sledge (it is not gaining kinetic energy or gravitational potential energy nor working against a friction force).

Question 18

Several candidates found this question difficult, with as many choosing option **A** or **B** as the correct answer **C**.



The rate at which thermal energy is dissipated is the work done per second against the friction forces.

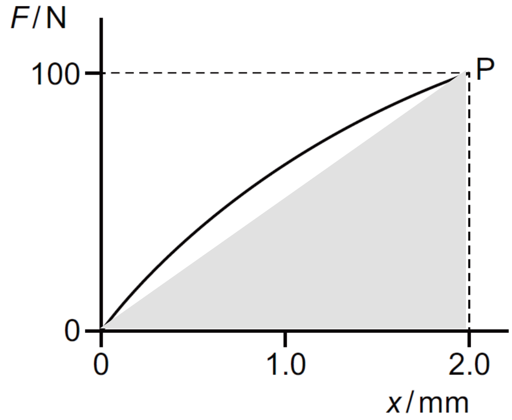
Using $P = Fv$:

$P = Fv = 2100 \times 25 = 5.3 \times 10^4$ W (Answer **C**)

Some candidates chose answer **A** as the overall force on the car is zero; others multiplied the component of the car's weight down the slope by the speed of the car (answer **B**), but this is the gravitational potential energy gained by the car each second.

Question 20

Many candidates found this question difficult. The work done in stretching the wire to point P is the area under the force-extension graph. This must be a little bigger than the area of the triangle shaded below:



This area is $\frac{1}{2}\times 2.0\times 10^{-3}\times 100 = 0.10\,\text{J}$, so the correct answer to the question is 0.11 J (answer **C**). It cannot be 0.20 J as this is the area of the rectangle formed by point P and the axes of the graph.

Question 26

The majority of candidates answered this question correctly (answer **C**) though a significant number of candidates chose answer **B**. As one end of the stationary wave is a node and the other end is an antinode the length of the tube must be an *odd* number of quarter-wavelengths, i.e.:

$$L = (2n-1)\frac{\lambda}{4}$$

for n = 1, 2, 3… where L is the length of the tube and λ is the wavelength. Hence the frequency f heard is:

$$f = \frac{v}{4L}(2n-1)$$

where v is the velocity of sound.

The first four frequencies are $\frac{v}{4L}$, $\frac{3v}{4L}$, $\frac{5v}{4L}$ and $\frac{7v}{4L}$. As the lowest frequency $\frac{v}{4L}$ is 92 Hz, the next three frequencies are 276 Hz, 460 Hz and 644 Hz.

Answer **B** is obtained if the length of the tube is *any* number of quarter-wavelengths (or half wavelengths).

Question 31

Just over half the candidates answered this question correctly (answer **D**); many others chose answer **A**. If the distance between the plates is decreased, the electric field strength $\left(\frac{V}{d}\right)$ would increase, which would increase the upward electrical force.

Question 35

Almost half the candidates calculated the combined e.m.f. and internal resistance of the two cells correctly; others calculated the combined internal resistance correctly, but *added* the two e.m.f.s, not taking into account the reversed polarity of the second cell.

PHYSICS

Paper 9702/22
AS Level Structured Questions

Key messages

- Candidates should consider checking whether their numerical answers have a plausible order of magnitude, as this check can often detect possible power-of-ten errors made in a calculation.
- Candidates should be encouraged to carefully read the command words used in each question. 'State and explain' indicates that an explanation is required as part of the answer.
- Candidates should choose their wording carefully, especially when giving a definition or explaining a situation. The omission or incorrect use of a key word can drastically alter the meaning of a response.

General comments

The marks scored by the candidates varied over the full mark range. Where a candidate did not attempt a response to a question part, this usually appeared to be due to a lack of ability rather than a lack of time.

Comments on specific questions

Question 1

(a) The majority of the candidates were able to give at least one of the two SI base quantities. Weaker candidates sometimes gave two SI base units instead of the required SI base quantities.

(b) (i) The vast majority of the candidates were able to calculate the acceleration of free fall. A small minority made an error when rounding their final answer.

(ii) Most answers were correct. A common mistake was to treat the percentage uncertainties in the period and length as absolute uncertainties. Some candidates did not realise that they needed to double the percentage uncertainty in the period before adding it to the percentage uncertainty in the length.

(iii) Generally well answered. Only the weakest candidates were unable to calculate the absolute uncertainty from their calculated value of the acceleration of freefall and its percentage uncertainty.

Question 2

(a) The vast majority of the candidates realised that they needed to use the Doppler effect symbol equation given in the Formulae Sheet. However, some candidates did not know how to apply the given symbol equation to the question and a common error was to confuse the observed frequency with the source frequency. Sometimes the speed of the sound in the water was confused with the speed of the dolphin. A significant minority of the candidates did not follow the instruction to express their answer to three significant figures.

(b) (i) The maximum height of the ball was usually calculated correctly. A very small number of the candidates that used the equation $v^2 = u^2 + 2as$ forgot to square the value of the initial speed when substituting it into this equation.

(ii) Although there were many correct answers, the most common errors were sketching a graph line from the origin and sketching a curved graph line.

(iii) The vast majority of answers were completely correct.

(iv) Although many candidates correctly stated that the acceleration of the ball would decrease, some incorrectly stated that the ball would have a deceleration. A full explanation for the decrease in the acceleration was rarely given. The full explanation is that the air resistance increases and acts on the ball in the opposite direction to the weight so that the resultant force on the ball decreases.

Question 3

(a) Some candidates only stated that the work done is equal to the force multiplied by the displacement. Successful responses explicitly referred to the 'displacement in the direction of the force'.

(b) (i) Most answers were correct. Weaker candidates sometimes calculated the work done using $140\,\text{N} \times 4.4\,\text{m}\,\text{s}^{-1} \times 30\,\text{s}$ which incorrectly assumes that the force on the man by the wire is in the same direction as his velocity.

(ii) The vast majority of the candidates could recall the general relationship between pressure, force and area. Most candidates were also able to calculate the vertical component of the tension force. A common mistake was to then add (instead of subtract) the magnitude of this component and the magnitude of the weight in order to calculate the downward force on the ground. Some candidates incorrectly assumed that the downward force on the ground was equal to just the weight of the man.

(iii) The general expression linking stress, force and cross-sectional area was reasonably well known. However, a significant number of weaker candidates made errors when calculating the diameter of the wire from its cross-sectional area.

(c) The stronger candidates were usually able to determine the change in the stain energy, although a significant number made power-of-ten errors by not converting the extension given in millimetres to metres. Weaker candidates sometimes calculated the wrong area under the graph line or simply confused strain energy and strain.

Question 4

(a) (i) Some answers needed to be more precise. For instance, it is insufficient to say that the wavelength is just the distance between two wavefronts rather than the distance between two *adjacent* wavefronts or the *minimum* distance between two wavefronts.

(ii) Most candidates knew that the amplitude of a wave is its maximum displacement. Some answers were spoilt by incorrectly referencing the displacement to a vague position such as 'the origin' or 'the horizontal line'. Others incorrectly specified that the maximum displacement must always be in the vertical direction.

(b) (i)1 The majority of the candidates correctly described the diffraction as the spreading of the waves at each slit in the grating. Some candidates incorrectly described diffraction as the bending of the waves when passing into a different medium.

(i)2 Many candidates correctly explained that waves are coherent when there is a constant phase difference between them. A significant number of candidates incorrectly referred to 'same phase difference' or 'zero phase difference' instead of 'constant phase difference'.

(ii) The majority of the candidates were able to recall the relevant symbol equation. A common error was to substitute into the symbol equation an angle of 68° instead of the correct angle of diffraction of 34°. A small number of candidates made errors when trying to convert the wavelength from units of nanometres into metres.

(iii) Usually answered correctly. A small minority of candidates correctly stated that the angle would decrease, but gave an incorrect explanation or omitted the explanation.

Question 5

(a) Many candidates could improve by being more precise when defining the ohm. Some simply defined resistance instead of the ohm. Others only stated that the ohm is the unit of resistance.

(b) The vast majority of the calculations were based on the correct symbol formula. The most common mistake was to make a power-of-ten error when attempting to convert the cross-sectional area from millimetres squared to metres squared.

(c) (i) Most candidates gave an answer in terms of the potential difference being shared between the resistors, rather than an explanation in terms of energy as required by the question.

(ii) Generally, well answered. A small minority of very weak candidates thought that the potential difference across X was equal to the electromotive force (e.m.f.) of the battery.

(d) (i) The majority of the candidates did not understand the effect of connecting battery Q in parallel with battery P. Only a small minority appreciated that the potential difference across the resistors would remain the same so that the current in them would also remain the same.

(ii) Only a minority of the candidates realised that the same total current is supplied to the resistors by the combination of the two batteries so that the current in battery P decreases.

(e) (i) This part of the question was usually answered successfully. A small minority of the weakest candidates gave the reciprocal of the total resistance as their answer.

(ii) The correct answer could be obtained by different methods. A significant number of weaker candidates did an incorrect calculation that assumed the potential difference across resistor Y was equal to the electromotive force (e.m.f.) of the battery.

Question 6

(a) The vast majority of the candidates were able to recall the relevant symbol formula for electric field strength and then calculate the correct separation of the plates.

(b) (i) Most candidates could state the appropriate general expression that relates electric field strength to the force and charge. This expression was usually used correctly to calculate the value of the charge in units of coulombs. A significant number of candidates were then unable to determine the charge in terms of ‘*e*’.

(ii) Although many candidates found this part of the question to be straightforward, a significant number of the weaker candidates did not know how to convert the mass of the nucleus in kilograms to the mass in atomic mass units.

(iii) The candidates who had obtained the correct answers to the previous two parts of the question usually went on to determine the number of neutrons in the nucleus. Many candidates did not realise that the answers to **(b)(i)** and **(b)(ii)** were equal to the number of protons and the number of nucleons respectively.

Question 7

(a) Most candidates correctly stated that the neutron was not a fundamental particle, although a significant number did not give the required supporting explanation. A significant number of weaker candidates incorrectly believed that the neutron was a fundamental particle because it was part of the nucleus of an atom.

(b) (i) The majority of the candidates stated the correct two leptons. A common mistake was to state that the leptons were an electron and an antineutrino.

(ii) Candidates found this part of the question challenging. Many candidates simply stated heat and/or light and some just stated the names of different particles without mentioning forms of energy.

PHYSICS

Paper 9702/33
Advanced Practical Skills 1

Key messages

- In choosing the number of decimal places of raw readings, candidates need to give the reading to the precision of the measuring device. For example, when using a metre rule a length should be stated to the nearest millimetre, e.g. 23.0 cm or 0.230 m.
- Graph axis scales should be chosen carefully so that they meet two requirements.
  First, it must be easy to read off a plotted value, so simple ratios such as 2 cm on the axis = 10 units or 2 cm = 5 units should be used.

  Secondly, the points should use at least half the grid in both directions. This means that they should occupy at least six 2 cm squares vertically and four 2 cm squares horizontally.
- Candidates need to understand the idea of significant figures so that they can apply the rule for calculated quantities given in Syllabus section 4.2.2. For example if L is 12.7 cm (3 s.f.) then $\frac{1}{L}$ should be given as 0.0787 cm^{-1} (3 s.f.) or 0.07874 cm^{-1} (4 s.f.)

General comments

Most centres had no difficulties in providing the equipment required for use by the candidates. Where a centre made a change to the specified equipment (normally following discussion with Cambridge International) it was noted in the Supervisor's Report so that examiners could take it into consideration when marking.

The report was also used if necessary to list any help given to candidates to enable them to take readings.

Candidates did not appear to be short of time, and nearly all answered all parts of the two questions.

For many centres, the standard of the candidates' work was very good, and there were many excellent papers.

For a few centres candidates seemed to have had limited practice in producing and analysing graphs.

Comments on specific questions

Question 1

(a) Most candidates recorded a value for x in range.

(b) Determining the time period was carried out well by many candidates, and there was very little misinterpretation of the timer display. In most cases credit was given for a value of T of around 1 s.

Examiners expected evidence of repeated measurements of $5T$ followed by averaging to find the value of T. In a few cases repeated measurements using only one oscillation were averaged, or the $5T$ value was treated as the period.

(c) Nearly every candidate collected six sets of data, although in a few cases the trend was wrong (i.e. T increased with x).

Many candidates used only part of the available range of x, often not reducing their x value below the initial value at all. The best candidates extended their range to less than 12 cm and more than 25 cm.

The standard of recording results was generally very good, with neat tables and clear headings. The only commonly incorrect or omitted unit was that for $\frac{1}{x}$.

In most cases measurements were recorded to the correct precision (see **Key messages**). If there was an error it was usually due to recording one or more of the x values to only the nearest centimetre.

Most calculated values of $\frac{1}{x}$ were correct, although some were rounded incorrectly ($\frac{1}{15}$ was often recorded as 0.066).

Only the best candidates gave their calculated values to enough significant figures (see **Key messages**).

(d) (i) Most graphs were of a good standard, with clearly labelled axes and scales.

Points were usually accurately plotted using small crosses (dots larger than 1 mm were not credited).

The points were often concentrated in only a small area of the grid (see **Key messages**).

The overall quality of the experimental results was judged by the amount of scatter. This can be made to look worse than it really is if the values are rounded too much so that the trend appears stepped.

If a point seems anomalous, candidates should be encouraged to check the plotting and then repeat the measurement if necessary. If such a point is ignored in assessing the line of best fit, the anomalous point should be labelled clearly, e.g. by circling the point. No more than one point should be labelled in this way – if two or more points are identified as anomalous their labelling is ignored.

(ii) Many candidates were able to draw carefully considered lines of best fit with a balanced distribution of points either side of the line along the entire length. Other lines needed rotation to get a better fit, or an anomalous point needed to be identified to justify the line drawn. Some candidates were not awarded credit because their lines were kinked in the middle or were drawn too thickly.

(iii) Good candidates used a suitably large triangle to calculate the gradient, and were credited for correct read-offs and calculation.

Working should always be shown, and values from the table should only be used if they lie on the line drawn.

Many candidates were able to read the y-intercept at $x = 0$ directly from the graph, but a large number of candidates incorrectly read off the y-intercept when there was a false origin. Other candidates substituted a read-off into $y = mx + c$ to determine the y-intercept.

(e) Most candidates recognised that a was equal to the gradient and b was equal to the intercept calculated in **(d)(iii)**. Further credit was given for the inclusion of correct units.

Question 2

(a) Most candidates were credited for their value of N. One or two centres all gave a value outside the expected range but since they matched the supervisor's value they were given credit.

(b) Most candidates recorded their value(s) of *L* to the nearest mm and included a unit.

(c) Many candidates recorded a deflection θ similar to the theoretical value of 12°, although some were smaller. This was a difficult measurement, and there was much evidence of sensible and careful procedures being used. Some lost credit because of incorrect precision (e.g. 14.0°) in their raw readings.

Reading the current I was more straightforward, but some candidates misinterpreted the display and gave an incorrect unit.

(d) Given the difficulty in measuring θ (due to parallax) the uncertainty was at least 2°. Many candidates realised this and used a sensible value in their percentage uncertainty calculation. A few mistakenly used their current values instead of θ.

(e) The calculation of *B* was generally carried out well. Any power-of-ten error was usually caused by failure to convert cm to metres or mA to amps (to match the unit on the answer line).

(f) Re-winding the coil with the turns closer together gives a theoretical deflection θ of around 30°, and this increase was used to judge the quality of the candidate's results. Credit was given in most cases.

(g) (i) The calculation of two *k* values was carried out well by most candidates.

(ii) *k* was calculated using the measurement θ together with *B*, and *B* was calculated using measurements I and *L*. The best candidates stated that the s.f. for *k* depended on the s.f. in I and *L* and θ (or that θ had the smallest s.f. in the calculation so *k* should have the same s.f. as θ).

(iii) The were many good answers for this question. These were all based on the idea of looking at the percentage difference between the two *k* values and then deciding whether it was higher or lower than the candidate's stated criterion.

(h) Many candidates found this section challenging. Description of difficulties must have sufficient detail and reasoning, and suggestions for improvement must be correctly described. Clarity of thought and expression separated the stronger candidates from those less practised in dealing with the limitations of equipment.

Most 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.

The apparatus itself caused some problems. Some candidates reported problems with rewinding the wire evenly due to kinks, and gained further credit for suggesting using new wire for the second coil. The lightweight plastic channel was difficult to keep in the same position while the angle readings were taken, and suitable method of fixing it to the bench was accepted.

The measurement of the deflection θ of the compass needle presented the main experimental difficulties.

Firstly, the uncertainty in θ was large compared to its value, so the percentage uncertainty was large. Many candidates wrote that the deflection was small so it was '*difficult to measure*' or '*not accurate*' but these statements were not accepted. The situation could be improved by making the deflection larger by increasing the current. Some candidates' descriptions ('*use a bigger battery*', '*use a more powerful cell*') didn't use correct terminology.

Secondly, the need to hold the protractor above the coil meant that its scale was at a distance above the compass and so there was parallax error when measuring the deflection. Many candidates suggested using a compass with angle divisions marked directly on it, and others suggested the alternative of photographing the deflected needle and measuring the angle on the photo.

The other measurement that gave difficulty was the current. Many candidates described a fluctuating ammeter reading. Most of these suggested that the cause was poor electrical contact in the circuit and went on to describe a method of cleaning clips and connectors as an improvement.

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 be careful that they do not give more than one answer to a question. This is particularly important when they are answering a question that asks for the definition of a quantity or the meaning of a symbol. These things only have one answer, and if multiple answers are provided that are contradictory, the candidate cannot be awarded credit for a correct answer.

Candidates need to take care to ensure that they read the question properly, understand what is being asked and give responses that answer the question that is asked. 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 part-credit even when the final answer is incorrect. Incorrect answers that are not supported by working cannot be awarded any 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 that changes the answer within the appropriate significant figures; 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 too few significant figures, and rounding intermediate answers prematurely, can both lead to full credit not being awarded.

General comments

There was a wide prevalence of answering a different question from the one asked, particularly in the various parts of **Question 4** on ultrasound. Previous mark schemes should not be memorised.

When 'show that' questions are asked it is vital that all stages are shown in the working. At the substitution stage, unit conversions (for example days to seconds in **1(b)(i)**) and the values of physical constants used must be shown (for example *G* in **1(b)(i)** and *R* in **2(a)**).

When asked to 'state and explain', candidates must give a reason with the answer. Many candidates in the final parts of **10** answered the 'state' part but gave no explanation.

It was encouraging to see that bookwork was generally well-known. However, candidates should be advised to offer a response rather than leaving a question blank. There was no evidence that candidates had insufficient time in which to complete the paper.

Comments on specific questions

Question 1

(a) Many candidates gained just one mark here. It is not enough to say 'gravitational potential is the work done in moving unit mass from infinity to a point'. Candidates need to be encouraged to use the phrase 'work done per unit mass' so that it is clear that the work done is divided by the mass.

(b) (i) This 'show that' question was well-completed by most candidates. A few responses did not include substituting in for 'G' and had slips in the substitution line. All squares need to be included and somewhere the conversion from days to seconds need to be seen.

(ii) Candidates found this part challenging. Common errors were to find gravitational potential instead of gravitational potential energy and by using GMm/(R – r) instead of GMm(1/R – 1/r).

(iii) There were a good number of correct responses here. Candidates were able to construct the correct ratio from the formula for gravitational field strength. The most common error was to forget to square the radius.

Question 2

(a) Most candidates were able to demonstrate that they could show the temperature of the gas. However, candidates need to clearly show where all numbers come from and this was important here for the calculation of the number of moles of the gas.

(b) This calculation was well-executed. The few responses containing errors tried to apply the first law of thermodynamics or had a power of ten error due to converting kg into g, or had used 350 K as the temperature change.

(c) This explanation was poorly completed. Most candidates gained a mark for saying the molecules collided with the walls of the container. However, they then went straight to a force or even straight to pressure. There was little reference to the change of momentum of the molecule and also there being a force on the molecule and hence a force on the wall.

(d) Responses demonstrated a confusion between mean-square speed and root-mean-square speed. Many candidates knew the relationship between mean-square speed and temperature but did not square root to find the required ratio.

Question 3

(a) (i) The question was well-answered.

(ii) There was a pleasing number of correct responses here. However, a significant number of candidates tried to apply incorrect physics ideas such as the constant speed formula or $a = (-)\omega^2 x$ and using velocity on place of acceleration.

(iii) Most candidates could identify where the body had maximum potential energy.

(b) (i) The majority of candidates could accurately state Faraday's law of electromagnetic induction. A few incorrectly referred to current and a few omitted the 'rate of change of'.

(ii) Candidates need to realise here that the key to the damping effect is the current that flows only after the switch is closed. This then creates a magnetic field around the coil that interacts with the field around the bar magnet causing an opposing force. The induced e.m.f. does not oppose the motion of the magnet. The induced e.m.f. was there before the switch was closed.

Question 4

(a) (i) Only a minority of candidates were able to explain why ultrasound in scanning is emitted in pulses. A significant number of responses confused the pulsing frequency with the frequency of the ultrasound.

(ii) The majority of candidates explained how the image is formed rather than how the reflected pulse is detected. References to time delay and depth as well as intensity and tissue type gained no credit.

(b) (i) Most candidates could apply the provided expression to calculate the intensity reflection coefficient. However, the most common reason for not gaining the mark was to not quote the answer to 3 s.f.

(ii) Candidates were aware of why the gel is used in the scanning process. However, their explanations were often incomplete, for example by not referring to intensity reflection coefficient as well and amount transmitted.

Question 5

(a) Many candidates were able to state two advantages. However, candidates need to be wary of stating more than the required number.

(b) (i) This calculation was well-completed. However, 3 s.f. data requires a 3 s.f. answer.

(ii) It was pleasing to see a good number of correct answers here. Some candidates could not use the 0.40 dB km^{-1} attenuation correctly and had the length in the incorrect place in their calculation.

Question 6

(a) This question was well-answered with most candidates correctly identifying the radius of the spheres.

(b) Candidates found this question very challenging. They did not realise that the point where the line crossed the *x*-axis where the electric field strength was zero meant that the electric field strength of sphere A was equal to the electric field strength of sphere B. Some candidates used incorrect physics by trying to apply the equation for force and some used the multiplication of both charges in the field strength equation (so effectively the force equation).

(c) (i) There were a good number of correct answers here. However, some candidates tried to use the incorrect sphere. Some candidates who used the kQ/r version of the formula then substituted the value of k in the denominator. Some candidates used the numerical value of the Boltzmann constant for ‘k’.

(ii) This calculation was well-completed. Most candidates gained at least one mark here by quoting the correct equation. Many candidates gained the second mark through error carried forward.

Question 7

(a) There were a good number of correct sketch graphs drawn. However, some candidates were unable to label the axes correctly, or drew lines that indicated the resistance increased as the temperature increased.

(b) Many candidates said that the resistance would decrease, but it did need to be clear that they were referring to the thermistor when they stated the resistance decreased. A majority of candidates did not give enough evidence to support the statement that the voltmeter reading increased.

(c) Candidates found this calculation challenging. They were unable to interpret the graph and deduce that $\Delta R/R$ was 9.0×10^{-2}.

Question 8

(a) A good number of candidates were able to explain what is meant by a magnetic field. It is best to limit the number of examples of what the force acts on to just one, as when there are more than one they must all be correct.

(b) The most common error here was to use the incorrect length. Candidates found it difficult to extract the relevant information from the data given. It was pleasing to see that candidates were able to interpret the graph here.

(c) (i) Candidates found it difficult to explain why the electrons followed a circular path.

(ii) While there were many examples of measurements that were not incorrect, for example the velocity of the electrons which cannot be directly measured, there were also many correct measurements stated as well.

Question 9

(a) (i) Around three-quarters of the candidates were able to calculate the root-mean-square value of the voltage of the supply.

(ii) While there were a considerable number of correct responses, a good number of candidates found it difficult to identify the angular frequency from the equation given. Those that could were able to calculate the time period, with just a few making errors in the rearrangement required.

(b) Only around 10 per cent of candidates were able to answer this question. Many thought the dissipated powers would be the same as the time period and amplitudes were the same. Of those who thought there were not the same, a good number did not refer to the r.m.s. values of the voltage but referred to incorrect ideas such as the area under the line.

(c) (i) There were a good number of correct answers here. However, some candidates were not clear about the use of r.m.s. and peak values.

(ii) On the whole there was not enough information given in responses here. Referring to just heat losses without a location and reason for them was insufficient.

Question 10

(a) Candidates need to remember that the photoelectric effect only takes place when photons are incident on the metal surface and that the photons supply the required energy.

(b) (i) Around half of the candidates were able to interpret the graph to find the work function energy. Many used the end of the line rather than extrapolating back to the *x*-axis. In addition, a significant proportion did not include the 10^{-19} with the energy value.

(ii) Candidates were required to show evidence for their answer here. When a value is reached that is not one of the options stated candidates should be encouraged to check their method for an error.

(c) (i) This question proved to be very challenging. Whilst many candidates knew that the kinetic energy of the electrons would not change, they were not able to link this to the energy of the photons.

(ii) More candidates than in **(i)** were able to correctly link the rate of emission here with the rate of arrival of photons.

Question 11

(a) This question proved to be quite challenging. Many candidates were unable to calculate the frequency of the X-ray photons from the accelerating p.d.

(b) This explanation was not well-known by candidates. There was considerable confusion with the aluminium filter acting as a collimating device and hence improving the quality of the image.

(c) (i) It was pleasing to see a good number of correct calculations here, however many candidates stopped at the percentage transmitted, rather than the percentage absorbed. However, weaker candidates just multiplied the linear attenuation coefficient by the thickness of the blood and did not use the decreasing exponential relationship.

(ii) Most candidates were able to explain that the bones were shown as white regions and the muscles were shown as dark regions. However, there was often an incomplete explanation linking the amount of absorption with the linear attenuation coefficient.

Question 12

(a) While candidates knew that this was the energy required to separate the nucleons, only a minority of them included that they were separated to infinity.

(b) (i) This question was well-answered, with the most common error being in '*y*', the number of neutrons.

(ii) This question was well-answered.

(iii) There were a significant number of candidates who got this comparison the wrong way around. There was perhaps confusion between binding energy and binding energy per nucleon.

(c) This calculation proved fairly challenging, with around one third of candidates reaching the correct answer. Responses showed that candidates could not correctly interpret the ratio between the two types of nuclei.

PHYSICS

Paper 9702/52
Planning, Analysis and Evaluation

Key messages

- Candidates should be encouraged to read the questions carefully before answering them. Planning a few key points before commencing **Question 1** is useful.
- In **Question 1**, candidates' responses should include detailed explanations of experimental procedures such as how to control variables, how to take measurements and how to analyse the data.
- In **Question 2**, graphical work should be carefully attempted and checked. Candidates should take care when reading information from the graph and understand the labelling of the axes.
- The numerical answers towards the end of **Question 2** require candidates to show all their working particularly when determining uncertainties. A full understanding of significant figures and the treatment of uncertainties is required.
- The practical skills required for this paper should be developed and practiced with a 'hands on' approach.

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. Apparatus relevant to the experiment must be labelled (e.g. magnet, spring and coil) and circuit diagrams should be drawn carefully and correctly. Candidates must also describe the measurements needed to determine the other quantities in the given relationship so that the constant α may be determined. A large number of candidates clearly identified how the constant α could be determined using the gradient. Many candidates did not provide enough additional detail. It is essential for candidates to have experienced practical work in preparation for answering this paper.

In **Question 2**, 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. Some candidates did not round the calculated values in the table correctly. Candidates should be encouraged to check the plotting of points that do not appear to be part of the line of best-fit. To be successful in the analysis section, candidates should ensure that mathematical working states the equation used with correct substitution of numbers and the answer calculated with a unit including the correct power of ten and significant figure. Candidates who set out their working in a logical and readable manner generally scored more marks. Many candidates did not realise that a logarithm of a quantity is a number and has no unit. Taking the antilog to obtain the value of the quantity will have units of that quantity. In this investigation, the current I was measured in units of microampere, μA, so ln (I/ μA) has no units. Many candidates experienced difficulties in dealing with powers of ten in the calculations in **parts (d)(i)** and **(e)**.

Comments on specific questions

Question 1

Most of the candidates correctly identified the independent variable (x) and dependent variable (E) from the given equation. Candidates should be encouraged then to consider the control of variables and to explicitly state the quantities that need to be kept constant to make the experiment a fair test. Good candidates clearly stated that the mass m and the magnetic flux density B of the magnet, the spring constant k of the spring and the number of turns of the coil N were kept constant. There was also an additional detail mark for stating that the distance between the equilibrium position and the coil must remain constant. Some candidates produced a list of quantities which were either not relevant to the equation or not appropriate. A small but significant number of candidates used the incorrect term 'control' rather than the correct term 'constant'.

Credit was available for the method of data collection. The drawing of a labelled diagram must show a workable set up. Good candidates attached the spring to a clamp in a retort stand, positioned the coil below the magnet in the correct orientation and clearly labelled the spring, magnet and coil. A further mark was awarded for the circuit diagram to measure the e.m.f. of the coil using either a voltmeter or oscilloscope. This mark was not scored if extra electrical components were added to the circuit.

The measurement of x by a meter rule presented difficulty to many candidates. A vague statement such as 'x can be measured by a ruler' was not creditworthy. In this experiment, the ruler reads the position of two point, either the position of a chosen point on the magnet or the spring could be used. The length x is obtained by the subtraction of the reading on the rule of the position at equilibrium and the position when displaced. Several candidates were not clear they were measuring the equilibrium and displaced positions, using phrases like 'original and final readings,' without qualification or original length of the spring. This mark could be scored from the diagram showing positions of the magnet in the equilibrium position and displaced position, clearly indicated on a labelled ruler and the distance x marked. Good candidates often gained an additional detail showing the ruler clamped in a stand with a set square positioned appropriately at the base of the rule with the bench.

The mark for the measurement of the mass, m, of the magnet by a balance was scored by the majority of candidates. Weighing scale/machine did not score.

Credit was available for the analysis of data. The majority of candidates selected the correct axes for the graph. 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 writing $y = mx + c$ under an expression.

A mark was available for explaining how the graph would confirm the suggested relationship. Candidates needed to use the words 'relationship is valid if' and the word 'straight' to describe the line which passes through the origin. If candidates plotted log-log graph, then the gradient of the line needed to be stated for this mark to be awarded

Having suggested an appropriate graph, candidates then needed to explain how the gradient could be used to determine the constant α. The constant α needed to be the subject of the equation.

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

Credit was available for a safety precaution. A clearly reasoned precaution relevant to the experiment was required, including a reason why the safety precaution is selected. In this experiment, many candidates explained correctly the use of a sand box to catch a falling magnet. There were a significant number of candidates who did not attempt to give a precaution despite being told to do so in the question instructions.

Two other detail marks that were well answered were the repeating and averaging of the e.m.f. for the same displacement and the measurement of the flux density B by a Hall probe. An extra mark was available for more detail in using the Hall probe practically – it is good practice to adjust the Hall probe so that a maximum reading is obtained and to measure the flux density in one direction and then reverse the Hall probe and measure the flux density again and find the average.

Other creditworthy additional detail not already mentioned included a method for determining the spring constant *k* of the spring. Details of a separate experiment was required, including an explanation of how *k* was determined. This included making *k* the subject of the formula used and realising that 'x' was not the extension of the magnet at equilibrium. Some candidates plotted force extension graphs and stated that the gradient was the spring constant.

Checking the unstretched length of the spring or the spring was not permanently stretched was rarely seen Very few candidates gave methods to maximize *E* or how to determine the value of the maximum *E*. Detailed explanations were needed for video methods including frame by frame playback.

Question 2

(a) Most candidates were able to work through the algebra and correctly gave expressions for the gradient and *y*-intercept.

(b) Completing the table was straightforward. Some candidates did not consider the appropriate number of significant figures. Since the data collected was all given to two significant figures the number of decimal places in the logarithmic quantities should have been either two or three. In some tables there were errors in rounding. Most candidates found the uncertainties correctly.

(c) (i) The data points and error bars were straightforward to plot. The points should be plotted to the nearest half small square. A number of candidates drew large 'blobs' for the plotted points which could not be given credit. Candidates need to take greater care over the accuracy of the error bars and ensure that each error bar is symmetrical about the plotted point.

(ii) The drawing of the straight lines has continued to improve. Candidates who are successful appear to be using a sharp pencil and a transparent 30 cm ruler which covers all of the points. Candidates should ensure that there is a balance of points about the line of best fit. The worst acceptable line was drawn well in general with a noticeable number of strong candidates drawing a line which passed through all error bars. Candidates should clearly indicate the lines drawn. Where a dashed line is used to represent the worst acceptable line, the dashed parts of the line should cross the error bars.

(iii) Most candidates clearly demonstrated the points that they used to calculate the gradient. Some candidates misread coordinates or did not use a sufficiently large triangle. A small number of candidates chose points that did not lie on the lines. Candidates should be encouraged to read carefully the quantities from the axes and to pay attention to powers of ten and units. In this experiment, the *y*-axis was a logarithm – some candidates incorrectly used 10^{-6} in their value of the gradient.

When determining the uncertainty in the gradient, candidates need to show their working including the coordinates that they have used from the worst acceptable line.

(iv) Since the *x*-axis had an origin, the value of the intercept could be directly read from the *y*-axis to less than half a square. A significant number of candidates chose to obtain the intercept by substituting a data point form the best fit line and the gradient value into $y = mx + c$. In this case since the *y*-intercept has no units since a logarithm is plotted on the *y*-axis.

(d) (i) Candidates must clearly show how the gradient and *y*-intercept were used. Credit is not given for substituting data values from the table into the expression. Many candidates were able to use the appropriate equation and the gradient to obtain a value for *C*. Arithmetical error of reciprocals or incorrect significant figures were the common mistakes.

Most candidates understood the method to determine *E* – the relevant equation was stated with correct substitution of numbers. Some candidates confused natural logarithms with logarithms to base ten. Candidates who did not understand the units often calculated *E* to have a value of about 7 000 000 V instead of about 7 V.

The units for *C* and *E* had many combinations of other electrical and base units rather than the Farad, F and Volt, V. A common error was to write the unit for capacitance as $s\,A^{-1}\,\Omega^{-1}$ rather than $s\,\Omega^{-1}$.

(d) (ii) Good candidates did set out their working clearly in order to show good understanding. Mistakes included omitting the percentage uncertainty in the gradient, subtracting instead of adding percentage uncertainties and not converting the percentage uncertainty in *C* to its absolute uncertainty. A very small minority of candidates who found the answer via maximum or minimum values generally scored the mark. In this latter method, care was needed to ensure that the correct maximum and minimum values were used; the mark could only be scored with clear working including the substitution of numbers.

(e) Candidates needed to fully understand the powers of ten in this part. A large majority of candidates substituted their values for *C* and *E* into the given equation and showed a good working method to obtain a numerical answer for the current, I, but often with a wrong power of ten either from *C* or *E*. A small number of candidates correctly used the gradient and intercept but failed to score because they calculated an answer in amperes (A) rather than microamperes (μA).