PHYSICS

Paper 9702/12
Multiple Choice

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

General comments

Candidates are advised to read each question in its entirety before looking at the possible answers, taking particular care with questions such as *Which statement is* ***not*** *correct?* and questions involving graphs where the axes may be the other way around from the way they are normally drawn. All the information in the question should be used to perform a calculation or draw a conclusion.

Candidates found **Questions 3**, **10**, **21**, **24, 32** and **36** more challenging. They generally answered **Questions 2**, **5**, **15**, **19**, **22**, **23**, **25**, **29**, **35** and **37** well.

Comments on specific questions

Question 3

The majority of candidates recognised that the pilot of the aircraft would have to steer in a direction west of north in order to fly due north. Some calculated the bearing angle as $\tan^{-1}\left(\frac{85}{200}\right) = 23.0°$ (option **B**) rather than $\sin^{-1}\left(\frac{85}{200}\right) = 25.2°$ (option **D**).

Question 4

Most candidates realised that the current increases when the load increases, eliminating options **B** and **D**. From the data given in the question, increasing the load by a factor of 6 only increases the current by a factor of 4, indicating that the gradient of the graph must be decreasing (graph **A**).

Question 6

Many candidates chose the incorrect option, **B**. The velocity of the mass at any time t is the gradient of the distance-time graph. At time $t = 0$, when the distance is a maximum (negative) value, the gradient of the distance-time graph is zero, so the velocity is zero.

Question 7

A significant number of candidates chose **A** or **D** rather than the correct answer, **C**. Candidates choosing option **A** simply divided the displacement by the time taken. Candidates choosing **D** did not account for the displacement being in the opposite direction to the initial velocity of the stone.

Question 8

Candidates needed to recall and apply the equation

velocity of separation = velocity of approach

for an elastic collision, taking particular care with the signs of the different velocities. Some candidates calculated the velocity of approach as $15 - 5 = 10\ \text{m s}^{-1}$ rather than $15 + 5 = 20\ \text{m s}^{-1}$, choosing option **A** rather than the correct answer, **B**.

Question 9

Many candidates chose **B** or **C** rather than the correct answer, **A**. If air resistance is significant, the horizontal component of the ball's velocity must decrease. Air resistance will also mean the downwards acceleration of the ball will be less than g, so the time taken to reach the ground will be greater than T.

Question 10

Many candidates found this question challenging, with many choosing option **B** rather than the correct answer, **C**. The total momentum before the collision is zero, so the total momentum after the collision is zero – the ball of mass $2m$ must rebound with velocity $v/2$. The loss in K.E. is then

$$\Delta(\text{K.E.}) = \left[\frac{1}{2}m(2v)^2 + \frac{1}{2}2m(v)^2\right] - \left[\frac{1}{2}mv^2 + \frac{1}{2}2m\left(\frac{v}{2}\right)^2\right] = \frac{9}{4}mv^2$$

Question 11

Many candidates chose option **A** or **D** rather than the correct answer, **C**. As the ball is falling at constant speed, the sum of the upthrust and drag forces must equal the weight force. All three forces remain constant as the ball falls. The upthrust depends on the pressure difference in the liquid between the top and bottom of the ball ρgh, where h is the height (diameter) of the ball, so is constant.

Question 12

Some candidates only calculated the torque needed to keep one of the four carriages rotating (option **B**); others calculated the torque taking the distance between opposite carriages as 3.20 m.

Question 13

Some candidates calculated the tension in the cord with all the weight of the beam OX concentrated at end X rather than uniformly distributed along the length of the beam. Other candidates probably calculated the perpendicular distance between the tension force in the cord and point X as $4.0 \tan 30°$ rather than $4.0 \sin 30°$.

Question 16

Many candidates gave the correct answer, **D**. Some candidates chose option **B**, omitting *g* from their calculation of the gravitational potential energy gained by the containers per unit time.

Question 17

Many candidates answered this correctly. However, other candidates converted the fuel consumption from litres/hour into litres/second incorrectly – the term "60 × 60" should appear in the numerator of the final expression.

Question 20

The majority of candidates answered this question correctly (option **D**). Most of the other candidates assumed the spring constants of the two springs should be added together, giving an overall spring constant of $10\ \mathrm{N\,m^{-1}}$, which would then stretch 8.0 cm when supporting a load of 80 N (option **A**).

Question 21

Many candidates found this question challenging with the majority reading the value of the extension when $F = 80$ N and then substituting values into the equation $E = \frac{1}{2} Fx$ to obtain option **B**. The correct answer is obtained by estimating the area under the graph up to $F = 80$ N by, for example, counting squares. There are approximately 22 large squares making the value of the strain energy 0.88 J (option **C**).

Question 24

Many candidates chose either **A** or **C**. For a stationary sound wave to be formed in the pipe, the closed end of the pipe must be a (displacement) node and the open end an antinode. The first four stationary waves have wavelengths of $4l, \frac{4}{3}l, \frac{4}{5}l$ and $\frac{4}{7}l$ where l is the length of the pipe. The corresponding frequencies are f_1, $3f_1$, $5f_1$ and $7f_1$, making the correct answer **D**. (Option **C** is obtained by treating both ends of the pipe as nodes.)

Question 27

Most candidates recognised that points S and T on the stationary wave would have the same amplitude of oscillation, but some thought that the two points would oscillate in phase rather than with a phase difference of 180°.

Question 28

Most candidates chose either option **A** (the correct answer) or option **B**. At a point of minimum intensity, the sound waves will not cancel out completely; the sound waves from the two speakers have travelled different distances so will have different amplitudes.

Question 30

Almost all candidates calculated the magnitude of the electric field strength correctly, though some chose the wrong direction for the electric field. As the upper plate is at a potential of +50 V relative to the lower plate, the force on a positive test charge placed between the two plates would be downwards (option **A**).

Question 32

Only the strongest candidates answered this question correctly. The quantity v in the equation $I = Anvq$ represents the average drift velocity of the charge carriers, not the velocity of each charge carrier. The instantaneous velocity of any individual charge carrier could be very large, due to the random thermal (Brownian) motion of the charge carriers. The slow movement of the charge carriers as a whole along a wire is very small by comparison.

Question 33

Most candidates chose either option **A** or option **C** (the correct answer). From $P = \frac{V^2}{R}$, the power dissipated in each resistor is inversely proportional to the resistance of each resistor. The ratio $P_2 : P_3 : P_4$ is $\frac{1}{2} : \frac{1}{3} : \frac{1}{4}$ which equates to 6 : 4 : 3. Option **A** is obtained by assuming $P \propto R$ (as would be the case if the three resistors were connected in series).

Question 34

As many candidates chose option **D** as option **A** (the correct answer). Candidates needed to notice that the current I was plotted on the x-axis, with the potential difference V on the y-axis (in many textbooks the voltage-current characteristic for a filament lamp is drawn with the potential difference on the x-axis).

Question 36

This question proved to be quite difficult for many candidates, with many candidates choosing options **A** or **C** rather than the correct answer, **B**. For the circuit given in the question

$$I = \frac{E}{R + r} \quad .$$

When $r = 0$, $I = \frac{E}{R}$ a non-zero but finite value (eliminating graph **A**). As r increases, $I \rightarrow \frac{E}{r}$, i.e. the relationship is non-linear (graph **B** rather than **C** or **D**).

Question 39

More candidates chose option **C** than option **D** (the correct answer), omitting to include the single neutron fired into the $^{235}_{92}U$ nucleus in their calculations.

PHYSICS

Paper 9702/22
AS Level Structured Questions

Key messages

- Candidates **should ensure they are familiar with the precise definitions and meanings of the terms in the syllabus.**
- For questions containing the command word 'show', it is essential that candidates clearly show all the steps in their derivation. Each step must be explicitly presented and then the final answer should be given.
- Candidates should always pay particular attention to the command words used in each question. A question containing the command to 'state and explain' indicates that an explanation is required as part of the answer. Therefore, candidates will not be able to obtain full credit if their answer contains only a statement without an explanation.

General comments

A range of performances was seen with most candidates able to complete the paper in the allotted time. The vast majority of the candidates attempted all parts of all questions.

Comments on specific questions

Question 1

(a) Almost all candidates could state at least one SI base unit. The most common answers were kilogram and kelvin. Candidates were given credit for stating mole and candela, although those units are not part of the AS Level content of the syllabus. It was inappropriate to give both the base units and the corresponding base quantities when the question only asks for the base units.

(b) Most answers correctly stated the SI base units for speed and for force. A common mistake was to state the base units of charge as either C or $A\,s^{-1}$. Candidates needed to take care with the powers of the base units when combining them to achieve the final answer. The strongest answers presented all the working as a series of discrete steps.

Question 2

(a) (i) Displacement is defined as the distance in a specified direction from a point. Although most candidates referred to distance in their answer, many did not explicitly refer to the distance being in a specified direction.

(ii) Most candidates were able to correctly define acceleration. A small number incorrectly defined it as the 'rate of velocity' or as the 'rate of change of velocity per unit time'.

(b) (i) Most candidates were able to explain that the man must be in equilibrium because he is travelling with constant velocity. The strongest answers explained that the man had zero acceleration and so there must be zero resultant force acting which means he was in equilibrium. A common misconception among weaker candidates was that the man could not be in equilibrium because he was moving.

(ii) The majority of the candidates showed the correct derivation of the value of the difference in height. A small number of weaker candidates thought that the man was accelerating and therefore inappropriately attempted to use an equation representing uniformly accelerated motion.

(iii)1 Most candidates were able to use the decrease in height of the man to calculate the decrease in his gravitational potential energy. A small minority of weaker candidates incorrectly gave the man's kinetic energy as their final answer, probably due to the misconception that the man's kinetic energy was equal to his decrease in gravitational potential energy.

(iii)2 There were two possible methods for calculating the air resistance acting on the man. The first method was to recognise that the decrease in gravitational potential energy is equal to the work done against the air resistance. Therefore the air resistance can be calculated by dividing the decrease in gravitational potential energy by the distance travelled by the man. The second method was to recognise that the man is in equilibrium so that the component of his weight in the direction along the glide path must be equal to the air resistance. A common error was to equate the weight of the man to the air resistance, even though those two forces act in different directions.

(iv) Although the majority of the candidates attempted to use the correct symbol equation, given on the Formulae Sheet, a common error was to calculate the density by using the pressure at one point only instead of using the difference in pressure between the two points A and B.

Question 3

(a) Stronger candidates were able to equate the components of momentum in the direction given in the question. However, there were a significant number of candidates who did not resolve the momentum of ball Y in the required direction. These candidates usually incorrectly equated the magnitude of the initial momentum of ball X, with the magnitude of the initial momentum of ball Y, even though the two balls were moving in different directions.

(b) The majority of the answers did not correctly consider the vector nature of the different momenta. Often candidates attempted to equate the magnitudes of the different momenta without taking into account their directions. Candidates needed to consider the vector nature of momentum when applying the conservation of momentum to interactions between bodies in two dimensions.

(c) This part of the question was generally well answered. The vast majority of answers used the correct symbol formula to calculate the difference in kinetic energy. A very small number of candidates recalled the correct symbol formula, but then forgot to square the value of the speed when substituting it into the formula.

Question 4

(a) The electric field strength at a point is the force per unit charge acting on a positive charge at that point. Many candidates incorrectly referred to the 'force on a unit positive charge' which does not make the ratio clear between force and positive charge. Others stated that it was the 'force per unit charge' without referring to positive charge. A small number of candidates inappropriately described a general electric field by stating that it was 'a region where a charge experiences a force'.

(b) (i)1 In general, this part of the question was very well answered. Almost all candidates could state the appropriate symbol equation. A small number of candidates either incorrectly transposed the equation or made a power-of-ten error when substituting the value of the potential difference.

(i)2 Many candidates correctly indicated that the bottom plate would have a positive charge and the top plate would have a negative charge. Most candidates failed to mention that both the plates would be horizontal.

(ii) The magnitude of the force was often calculated correctly, although a small proportion of candidates calculated the force based on a total charge corresponding to a single electron, rather than the required total charge corresponding to three electrons. The direction of the force was more likely to be incorrect. Weaker candidates often incorrectly stated that the force would act upwards, possibly because the electric field is in the upwards direction.

(iii) The calculation of the angle of the rod proved to be challenging for most candidates. The most common error was to use the wrong trigonometric function ($\sin\theta$ instead of $\cos\theta$) when writing down the expression for the torque of the couple.

Question 5

(a) (i) Candidates needed to state the principle of superposition in precise terms. Some candidates only said that the waves 'superpose' which just paraphrased the question. It was important to state that the waves must overlap and that the resultant displacement is the sum of the displacement of each wave. A common mistake was to say that the 'resultant wave is the sum of the individual waves' which was too vague as there was no mention of displacement. Another common mistake was to refer to amplitude instead of displacement.

(ii) Stronger candidates knew that coherence means there is constant phase difference between the waves. Weaker candidates often incorrectly stated that coherence meant that the waves must be in phase. It was insufficient to describe coherence as meaning that the waves only needed to have the same frequency.

(b) Many candidates stated the correct general relationship between intensity and amplitude. Most candidates found it challenging to apply this relationship to the question. A common error was to calculate the resultant amplitude due to both waves at the point of intersection instead of calculating the required amplitude of wave Q.

(c) (i) The relevant symbol equation was usually stated correctly. The most common mistake was to make a power-of-ten error when substituting either the value of the wavelength or the value of the fringe width.

(ii) Stronger candidates usually realised that the new line should be drawn beneath the printed line, although the new line was often incorrectly drawn from the same starting point on the vertical axis as the printed line. Very few candidates realised the gradient of the new line should be less than that of the printed line.

Question 6

(a) Most candidates found it challenging to give a precise answer to this question and many did not answer in terms of energy transformations as required by the question.

(b) (i)1 Most candidates calculated the current in resistor Z. The most common mistake was to think that the potential difference across resistor Z was equal to the e.m.f. of the battery.

(i)2 A correct symbol formula for power was usually stated. In most cases, the symbol formula was then applied correctly to the question. A small minority of candidates stated a correct symbol formula that included resistance, but then substituted the wrong value of the resistance.

(i)3 The charge that moves through the battery was usually calculated correctly. The calculation of the number of conduction electrons was more problematic for many candidates.

(i)4 There were several different methods for calculating the total resistance of resistors X and Y connected in parallel. The weakest candidates often tried to use the resistors in parallel formula that is given on the Formulae Sheet, but then usually gave up their attempt when they realised that they did not know the resistance of resistor X. A significant number of candidates inappropriately gave the total resistance of the entire circuit as their final answer.

(i)5 There were two different methods for calculating the resistance of resistor X. The most successful method was to use the resistors in parallel formula that is given on the Formulae Sheet. The other method was to calculate the current and potential difference for resistor X, although this method was rarely used and usually resulted in errors being made.

(ii) The stated change in the voltmeter reading often lacked a comprehensive supporting explanation.

Question 7

(a) (i) Most candidates were unable to state the three particles that are not fundamental. A common misconception was that that the beta-plus particle is not a fundamental particle.

(ii) This part of the question was answered correctly by most candidates.

(iii) Only a minority of the answers correctly identified the beta-plus particle as having the largest ratio of charge to mass. The majority of the answers incorrectly stated that it was the alpha particle, possibly because the alpha particle has the largest charge.

(b) Although stronger candidates found this to be a straightforward part of the question, there were a significant number of other candidates who seemed to simply guess the answer without giving the required supporting explanation. The majority of candidates did not know the charge of the antidown quark which was a key part of the required explanation.

PHYSICS

Paper 9702/33
Advanced Practical Skills 1

Key messages

- The ability to present calculated values to an appropriate number of significant figures is usually tested in each of the two questions. Many candidates had difficulty with this, particularly in tables where it may be necessary for the number of decimal places to change down a column of calculated values.
- It is appropriate to take repeated measurements where the quantity may show some variation, e.g. for timings or diameters. Candidates should record all their raw data and not just state the final mean value.

General comments

There was no evidence that Centres had any difficulties in providing the equipment required for use by the candidates. Many candidates' work was of a good standard. There did not seem to be a shortage of time and all sections of the two questions were answered by almost all candidates.

Comments on specific questions

Question 1

(a) Most candidates recorded the value of x to the precision of the measuring instrument (i.e. to the nearest mm).

(b) Most candidates recorded a value for T in the expected range. The strongest candidates measured $5T$ or $10T$ several times and then calculated the average period T. Some others repeated measurements of a single period. It is possible that many candidates took repeated timings, but some recorded only a single value.

(c) Nearly all candidates recorded six or more sets of values. In a few cases, full credit could not be given because each increase in x did not produce a decrease in T. The strongest candidates used the full range available by including both the first and last holes in the pendulum. Tables of results were generally clearly presented and most measurements were recorded to consistent precision. However, some tables did not include correct units in the column headings. The strongest candidates recorded their calculated values of $1/x$ to appropriate significant figures (e.g. $1/14.0 = 0.0714$). The majority of candidates calculated correctly but recorded an answer with too few significant figures (e.g. $1/14.0 = 0.07$).

(d) (i) Many graphs were drawn to a good standard, with accurate and clear plotting of the correct quantities and good use of the available grid area. Most scales were simple with divisions clearly labelled. In some cases, the points were drawn using dots that were too large. The clearest graphs used small crosses. The quality of the candidates' data was judged by the scatter of points about a straight-line trend, and in the majority of cases this was good and credit was awarded.

(ii) Stronger candidates drew suitable lines of best fit which had a balanced distribution of points either side along the entire length. In some cases, a stray point was apparently ignored without explanation. 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 can be ignored in this way.

(iii) Nearly all candidates knew how to find the gradient of their line. Most took values from their line and carried out the procedure accurately and showed their working clearly, although some used triangles that were too small. The intercept value could often be read directly from the T^2 axis. If this was not possible, candidates generally knew how to calculate the intercept using their gradient value.

(e) Most candidates recognised that *a* was equal to the value of the gradient and *b* was equal to the intercept. Most candidates also included correct units for their *a* and *b* values.

Question 2

(a) Most candidates included a unit with their value for *B*.

(b) Most candidates recorded a value for *d* to the nearest mm (the precision of the measuring instrument). Some also took several measurements across the irregular patch and took the average of these as the diameter.

(c) There were many good answers for the percentage uncertainty in *x* based on an absolute uncertainty of 2 mm or more. Some candidates looked at the spread of repeated readings and used half the range of these values, which was another valid method that was awarded credit.

(d) The calculation of the pressure *P* was generally well done, and a large number of candidates made sure that they converted their values of *m* to kg and *d* to m so that their calculated value matched the unit provided on the answer line.

(e) The strongest candidates gave a satisfactory justification for the significant figures they had given for *P*. Other descriptions omitted specific reference to one or more of the three quantities used in the calculation.

(f) Most candidates correctly repeated the experiment using the second balloon. In a few cases the relationship between balloon diameter and contact patch diameter showed the wrong trend.

(g) (i) Nearly all candidates calculated the two values of *k* correctly.

(ii) Discussion of whether the analysis in **(i)** supported the suggested relationship was carried out well by many candidates. Unsuccessful answers usually did not have a numerical comparison of the percentage difference of the *k* values with what would be an acceptable difference in this experiment. General or vague statements such as “valid because the values are close to each other” could not be awarded credit. Candidates needed to ensure their justifications were quantitative.

(h) Many candidates identified several areas of difficulty in this particular experiment – usually including parallax issues, movement of the balloon, and the difficulty of seeing the contact patch clearly. Workable improvements were slightly less common, often because they lacked sufficient detail. For example “use coloured water” wasn’t accepted unless it also mentioned contrasting with the balloon colour. Viewing the contact patch through the glass led to measurement errors due to parallax and refraction. Using thinner glass was accepted as an improvement as it would reduce both types of error. Many candidates were concerned that the quantity of water was different for each of the two balloons, but this was not accepted as it would not affect the size of the contact patch.

Credit was not given for suggested improvements that could be carried out in the original experiment, such as repeating measurements, doing more readings to get an average value or ensuring the reading is taken perpendicularly. Unrealistic solutions were also not given credit, e.g. “robotic arm” or “mechanical hand”. Problems that were irrelevant or that could have been removed if the candidate had taken greater care were not given credit. Vague or generic answers such as “too few readings” (without stating a consequence), “faulty apparatus”, “use an assistant” were also not given credit.

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

PHYSICS

Paper 9702/42
A Level Structured Questions

Key messages

- Candidates need to make sure they show full substitution in a calculation. This includes the substitution of numerical values for physical constants such as G in **1(b)(i)** and N_A in **2(b)(i)**.
- Final answers to numerical questions should be given to the same number of significant figures (or one more than) the data in the question.

General comments

Many candidates had prepared well for the exam, and showed excellent knowledge and application. However, some were not at the standard required for this A Level qualification. Few candidates were unable to finish in the allocated time. Handwriting was usually clear and calculations were generally presented well.

Comments on specific questions

Section A

Question 1

(a) (i) Most candidates gained partial credit for this question. The division aspect of 'work done per unit mass' is not clear when the candidate writes 'work done in moving unit mass'. Some candidates used the word 'force' (rather than 'work') needed to move mass from infinity.

(ii) Many candidates were able to make a start to this question (either by referring to zero potential at infinity or by observing that the gravitational force is attractive), but very few gave a full answer. Answers that discussed 'work needing to be done against gravitational force' were common and showed a fundamental misunderstanding by candidates in not realising that the mass is what does work when two masses approach. Many candidates did not refer to work or potential energy at all.

(b) (i) This calculation was completed accurately by many candidates. The most common error was to use the wrong radius by omitting to add the height of the satellite from the surface of the Earth.

(ii) This question proved challenging with many candidates using $E_P = mgh$ as a starting point or giving an expression for potential rather than potential energy. Most candidates who used the correct starting equation were able to find the correct numerical value. However, despite the detailed responses to **(a)(ii)**, few candidates realised that the answer had to be negative.

(c) Many candidates realised that the kinetic energy would increase, but did not have the correct reasoning for this assertion. A common misconception was to refer to the conservation of energy, which is incorrect given that the rockets on the satellite had been fired.

Question 2

(a) (i) Most candidates knew that the defining feature of an ideal gas is that it follows the equation $pV \propto T$. However, in order to gain full credit, the terms needed to be defined and in particular candidates needed to state that thermodynamic temperature needs to be used. A number of candidates gave assumptions of ideal gases instead.

(ii) This was well answered by many candidates However, some candidates did not realise that the order of the three words 'mean square speed' is important as 'mean speed squared' has a different meaning. Some candidates added the word 'root' and the weakest candidates thought that *c* was the speed of light.

(b) (i) This calculation was performed very well. Candidates needed to show full substitution, including constants, when the calculation is part of a question that includes the instruction to 'show that'.

(ii) This estimate was well completed. A small number of candidates stopped at the volume of one atom.

(iii) Many candidates found this a challenging question, and there was a lot of confusion about what is meant by the volume of the gas. Some gave answers merely in terms of 'greater than' or 'less than', without implying that it was negligible. In addition many candidates, despite the instruction to make reference to the answer to **(ii)**, made no numerical comparison.

Question 3

(a) (i) Many candidates found this question difficult. Incorrect forces named included 'air resistance' and 'viscosity'. These forces are not acting immediately after the tube has been released since it is not yet moving. Candidates should not list more than two forces when asked to give two as they will gain no credit for any responses given in this case.

(ii) Most candidates knew the resultant force was acting upwards. However, they could not explain that the upthrust was at that moment greater than the weight. It was not correct to say that the displacement and the resultant force are in opposite directions as this is the consequence of the direction of the resultant force, not the cause of it.

(b) Many candidates correctly identified the characteristic properties of shm ($a \propto -x$ or the equivalent in words). However, they did not identify that this was only true because ($A\rho g/M$) was constant.

(c) (i) This calculation was correctly completed by most candidates.

(ii) This calculation was well completed. Most errors were due to the incorrect conversion of the area from cm^2 into m^2 or using the incorrect value of 'g' and starting with the incorrect equation $\omega = A\rho g/m$. Another mistake made by weaker candidates was to square the area given, showing a misunderstanding of the data given.

Question 4

(a) The properties of a geostationary orbit were generally well known. Some candidates gave responses that focussed on the advantages and disadvantages of satellites placed in geostationary orbits, rather than answering the question and describing the properties of the orbits. There was often confusion between speed and angular speed, and suggestions that satellites in geostationary orbit have the same speed as the Earth.

(b) The attenuation formula needed for this calculation was well known. However, many candidates had the power ratio substituted in the wrong way (confusing the input and output powers), leading to an unrealistic received signal power. The received power cannot be greater than the transmitted signal power.

(c) Many candidates made good attempts at a response. However, some candidates confused geostationary and polar orbits when describing the advantages and disadvantages of the satellites. A common misconception was that polar satellites do not suffer from any time delay (whereas there is time delay associated with geostationary satellites), and therefore missed the comparative nature of the longer time delay associated with geostationary satellites.

Question 5

(a) Many candidates were able to state the meaning of an electric field. Mistakes included defining electric field strength and using the word 'field' instead of explaining it as a region or area.

(b) A significant number of graphs of the electric field strength were poorly drawn. Most candidates had a downwards curve of decreasing gradient with value of 1.00*E* at *R.* However, some were $1/r$ instead of $1/r^2$ curves, some did not go through any calculated points, and some either missed out the field strength inside the sphere or thought its value would be 1.00*E*.

(c) This was generally answered well. The most common misconception was to confuse electric field strength with electric potential. Another was to confuse the value given in the data page for $1/4\pi\varepsilon_0$ with $4\pi\varepsilon_0$ and the weakest candidates substituted in the value for the Boltzmann constant for *k*.

Question 6

(a) Most candidates were able to define capacitance as 'charge/potential' but the detail of charge on one plate or potential difference between the two plates was often omitted. The weakest candidates described capacitance as energy stored. Some candidates were confused by the phrase 'parallel-plate capacitor' and thought they were describing a set of capacitors connected in parallel.

(b) Many candidates answered both parts correctly. The most common errors were to use the wrong symbol for a capacitor, to confuse the way that capacitors combine with the way in which resistors combine, and to fail to make the connections to the combination clear.

(c) Most candidates gave a correct starting equation for the energy stored in a capacitor, but many did not recognise the significance of the discharge from 7 V to 4 V. Mistakes included working out the energy stored at 7.0 V only, doubling the correct value (since the graph went from 7.0 V to 4.0 V and back to 7.0 V in the required time) and mathematically evaluating $(7.0 - 4.0)^2$ instead of $7.0^2 - 4.0^2$.

Question 7

(a) The first part of this question was generally answered well, with most candidates correctly defining gain as the ratio of output voltage to input voltage. Most candidates were also able to give a good answer to the second part about infinite slew rate. Some confused cause and effect (thinking that the output results in the input), and others omitted the reference to changes in the signal.

(b) (i) Completing this circuit diagram proved challenging for many candidates. There was a wide variety of incorrect answers, but common errors were to reverse the input terminals and to connect the inverting input to Earth.

(ii) There were many correct answers here. Errors included missing the fact that R_1 was 12 kΩ, leading to a power of ten error, using the formula for a different type of amplifier and having the ratio of the two resistor values upside down.

(iii) Only the strongest candidates answered this question correctly. There was a wide variety of mistakes in the responses to this question, with full credit being awarded only to a minority of candidates.

Question 8

(a) (i) A small number of candidates gave a full, correct response to this question including reference to Newton's third law. Many candidates did not realise that the wire and the magnet were two separate entities. They correctly thought that the reading in the balance decreased as there was an upwards force on the magnet, but they described this as an upward force on the wire.

(ii) Many candidates were able to correctly deduce the direction of current flow consistent with their answers to **(i)**. The most common reason for not gaining credit was omission of reference to the Left Hand Rule in the explanation.

(b) A variety of answers was seen, with most candidates able to score some credit. However, cycles with double the correct period were common, as were those that did no show the correct amplitude of 6.4mN.

Question 9

Most candidates were able to identify that CT scanning makes use of X-rays and leads to a three-dimensional image of the structure being examined. The mechanism for achieving this, though 2D imaging of sections through the structure, was described with varying success. Responses given in terms of the image being sliced up were common but were not precise enough to be awarded credit.

Question 10

(a) A wide range of answers were seen for this question. Many candidates did not draw the pattern inside the solenoid, and some did not draw this part of the field pattern at all. Only a few drew straight, parallel lines through the full length of the solenoid. However, many candidates gained credit for showing the direction.

(b) Faraday's Law of electromagnetic induction was generally well known and well described.

(c) Only the very strongest candidates answered this question correctly. It was clear that the vast majority of candidates had no idea (and were unable to deduce) how the laws of electromagnetic induction applied to the scenario of the current in a solenoid being switched on. Many candidates focussed on the core instead of the coil and thought that eddy currents were responsible.

Question 11

(a) Many candidates correctly identified a photon as a quantum of energy. The association of this energy with electromagnetic radiation was less successful, with many candidates thinking that photons are 'emitted by' or 'carried by' electromagnetic radiation, rather than appreciating that the energy is electromagnetic radiation.

(b) This question was generally well answered. Common mistakes were the power of ten conversion from nm to m, and the conversion from J to eV.

(c) Many candidates gave creditable responses to this question, and the significance of electrons moving between the bands was fairly well known. However, some candidates did not make it clear that the electrons in the valence band absorb the energy of the photons and that it is the increase in the number of charge carriers that lead to the decrease in resistance. Many candidates used the numerical values given for the photon and the width of the forbidden band, but a significant number did not.

Question 12

(a) (i) Most candidates identified nuclear fission as the type of reaction, with only a small number thinking it was fusion. Unfortunately, a significant number of candidates gave two answers: fission and radioactive decay, and were therefore unable to gain credit.

(ii) Candidates who correctly identified the missing product as a ${}^{0}_{-1}e$ particle were generally also successful in identifying that there are 7 of them.

(b) (i) Many candidates used the correct starting equation and deduced a correct numerical answer. However, many also failed to recognise that the precision of the data provided in this question required an answer to 3 significant figures.

(ii) There were few correct answers to this question. There were a significant number of responses that included heat, light and sometimes even sound. Some candidates gave kinetic energy as their answer but failed to link this to the products. Other candidates said 'photons' or 'radiation' but did not specify this as gamma photons or gamma radiation.

PHYSICS

Paper 9702/52
Planning, Analysis and Evaluation

Key messages

- Candidates should read the questions carefully before answering them to understand what is required. Planning a few key points before commencing **Question 1** is useful.
- In **Question 1**, 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.
- The numerical answers towards the end of **Question 2** require candidates to show all of 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 practised with a hands on approach.

General comments

In **Question 1**, candidates should think carefully about the experiment following the points given on the question paper and should imagine how they would perform the experiment in the laboratory. There were some unworkable circuit diagrams drawn. A large number of candidates did well on the analysis section with clear identification of how the constants could be determined. 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 needed to 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. Stronger candidates clearly showed the points form their lines used to calculate the *y*-intercept. Some candidates did not realise that there was a false origin so the *y*-intercept could not be read directly from the *y*-axis.

In the last parts of the questions candidates needed to show mathematical working with a clear statement of 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 made fewer mistakes.

Comments on specific questions

Question 1

Most candidates correctly identified the independent and dependent variables from the given equation. Candidates then needed 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. Some candidates did not state the capacitance C was to be kept constant. Candidates also needed to state that the input voltage or V_i needed to be kept constant Some candidates produced a list of quantities which were either not relevant to the equation or not appropriate. Some candidates use the incorrect term "control" rather than the correct term "constant".

Credit was available for the method of data collection. In this experiment candidates were expected to draw a circuit diagram with a (d.c.) power supply and the neon lamp connected in parallel to the capacitor. There was also credit for correctly positioning voltmeters (or oscilloscopes) to measure V_i and V_F. Candidates also needed to determine the resistance of the resistors used. Stronger candidates drew a separate diagram for either an ammeter and voltmeter or ohmmeter method. A common error was to connect an ohmmeter in parallel with the resistor in the main circuit.

Some candidates were unsure about what the stopwatch/timer was to record. Its function was to measure time period or time for a given number of flashes of the lamp. Answers referring to frequency or number of flashes per unit time could not be credited. A stopwatch only drawn in the diagram without any explanation of its use was also not credited.

Credit was available for the analysis of data. The majority of candidates selected the correct axes for the graph. Candidates needed to explicitly state the quantities to be plotted on each axis either in the text or on drawn axes – credit was not given for writing $y = mx + c$ under an expression. Having suggested an appropriate graph, candidates then needed to explain how the gradient could be used to determine the constant K. It was not enough to state that for a T against R graph the gradient = KC, K needed to be the subject of the equation. Many candidates successfully determined a value for V_L using mathematical manipulation of the given logarithmic equation with V_L the subject of the formula. To gain credit 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.

In the additional detail section stronger candidates wrote their plans including appropriate detail. However, often candidates' answers suggested that they did not have sufficient practical experience. Vague responses were not credited. It was essential that candidates' answers were relevant to the experiment in the question rather than general rules for working in the laboratory.

Many candidates were able to give a clearly reasoned precaution relevant to the experiment, including a reason why the safety precaution was selected. In this experiment, using high voltage required protection of from electric shock/electrocution so an appropriate precaution would be switching off the circuit or wearing insulated gloves.

Other creditworthy additional detail included a method for determining the capacitance C. Stronger candidates drew a separate circuit diagram and explained how the value could be determined.

Question 2

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

(b) Most candidates successfully completed the table. However, some candidates did not consider the appropriate number of significant figures. Since the data collected was all given to the 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. Some candidates incorrectly determined twice the absolute uncertainty.

(c) (i) Most stronger candidates were awarded full credit. The points and error bars were often plotted corrected. The points needed to 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 needed to take greater care over the accuracy of the error bars and ensure that each error bar was symmetrical about the plotted point.

(ii) Many candidates who were successful appeared to have used a sharp pencil and a transparent 30 cm ruler which covered all of the points. Candidates needed to ensure that there was a balance of points about the line of best fit. For this particular set of data, the last point could have been treated as anomalous. The worst acceptable line was usually drawn well with a noticeable number of strong candidates drawing a line which passed through all error bars. Candidates needed to clearly indicate the lines drawn. Where a dashed line was used to represent the worst acceptable line, the dashed parts of the line needed to cross the error bars.

(iii) Most candidates demonstrated the points that they used to calculate the gradient clearly. 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. Stronger candidates read the quantities from the axes carefully and paid attention to powers of ten and units. In this experiment both axes were logarithms so there was no 10^{-3} in the value of the gradient. When determining the uncertainty in the gradient, candidates needed to show their working including the coordinates that they had used from the worst acceptable line.

(iv) Most candidates who were awarded full credit set out their working clearly. Stronger candidates often substituted a data point from the gradient calculation into $y = \mathrm{m}x + \mathrm{c}$. Some candidates incorrectly quoted the value on the *y*-axis where the best fit line cut the axis without realising that the graph had a false origin, i.e. the *y*-axis was not at $x = 0$. When determining the *y*-intercept of the worst acceptable line, candidates needed to clearly show the substitution into $y = mx + c$ of a point from the worst acceptable line and the gradient of the worst acceptable line from **(iii)**. Stronger candidates used a data point from their gradient calculation for the worst acceptable line.

(d) Candidates needed to clearly show how the gradient and *y*-intercept were used. Credit was not given for substituting data values from the table into the expression. Often candidates were able to show the use of the appropriate equation and the *y*-intercept to obtain a value for *p*. Some candidates incorrectly used 'e' rather than '10'. Candidates needed to show their working here and most candidates did this and were able to quote the value of the gradient as *q*. Some candidates gave incorrect powers of ten however.

(e) Only the strongest candidates answered this question correctly. A full understanding of powers of ten, units and logarithms was required. Stronger candidates showed logical presentation and full number substitution. The temperature θ, was found by taking logarithms of the given equation. A common error was using 0.10 rather than 100 for the given value of viscosity η – the quantities used in the table and graph were η / 10^{-3} Pa s.