PHYSICS

Paper 9702/12
Multiple Choice

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

General comments

It is important to carefully read the text of the question before looking at the answer options. Candidates should be familiar with the definitions of physical quantities in the syllabus and should recognise definitions for units and quantities.

In numerical questions, candidates should carefully consider SI prefixes and powers of ten and should be encouraged to check to their answers to make sure they are a sensible magnitude.

In general, candidates found questions **13**, **14**, **20**, **29** and **36** relatively difficult. Candidates found questions **1**, **2**, **9**, **16**, **24**, **27**, **30**, **33**, **38** relatively easy.

Comments on specific questions

Question 1

Most candidates answered this correctly, selecting option **A**. Some candidates chose the incorrect options **B** and **C**, not recognising the SI base units and how they differ from SI units, e.g., g and kg.

Question 3

Most candidates answered this correctly, selecting option **D**. Of the candidates who answered incorrectly, many selected the incorrect option **C**. These candidates were able to identify that the right-hand side of the equation must contain a square root, in order to match the units of *T* on the left hand side, but incorrectly re-arranged the units of *k* and *m*.

Question 4

Most candidates answered this correctly, selecting **B**. Of the candidates who answered incorrectly, many selected the incorrect answer **A**. These candidates may have confused resultant force with velocity, or think that force is proportional to acceleration, not to velocity.

Question 5

Most candidates answered this correctly, selecting **B**, but many chose the incorrect answer **A**, confusing the horizontal component of velocity for the magnitude of the velocity.

Question 6

Most candidates answered correctly (**B**) with **D** the most common incorrect answer. Answer **D** gives the total **distance** travelled by the ball, rather than the **displacement** from its initial position.

Question 7

The most common incorrect answer was **C**. A correct definition for acceleration is 'rate of change of velocity', which is equivalent to the correct answer **A**, 'change in velocity per unit time'. Answer **C** gives '**rate** of change of velocity **per unit time**', which is equivalent to acceleration divided by time.

Question 10

Most candidates selected the correct answer **C.** Some candidates selected the incorrect answers **A** and **D**, not recognising that as the ball moves with a constant speed, the resultant force acting on it must be zero.

Question 11

Most the candidates chose the correct answer **C**, correctly accounting for the cubic scale factor in the problem. Some candidates instead found the weight for a 2.0 m long line of 5.0 cm cubes, and so selected the incorrect answer **A**.

Question 12

Candidates found this question difficult. The correct answer can be found by equating the pressure at the bottom of the borehole with the sum of the pressures of each fluid in terms of the unknown height x.

Pressure at bottom of borehole = $17.5 \times 10^6 = 1000 \times 9.81 \times (2000 - x) + 830 \times 9.81x$.
This equation can then be solved for x to give the correct answer **D**.

Question 13

Most candidates realised that the moment would not vary linearly with θ (incorrect answer **C**) or remain constant (incorrect answer **A**). As moment is a vector, once θ passed 90°, the direction of the moment becomes opposite to its initial direction, so answer **D** is correct.

Question 15

Most candidates found this question straightforward, correctly selecting answer **C**. Some candidates chose the incorrect answer **A**, which is a valid way to calculate a resultant force but is not the definition of force.

Question 17

Most candidates answered this correctly, selecting option **D**. Some chose the incorrect answers **A** and **C**. Equilibrium requires both resultant force to be zero **and** resultant moment to be zero.

Question 18

Candidates found this question difficult. As energy is conserved, the smallest difference in kinetic energy will be the points with the smallest difference in gravitational potential energy, and so the smallest difference in height. Of the 4 points, Q and S are closest in height, so the correct answer is **A**.

Question 20

Candidates found this question difficult. Some candidates chose the incorrect answer **B**, thinking that the two particles have equal kinetic energy. As momentum is conserved, the less massive particle will have twice the speed after the explosion, and twice the kinetic energy of the more massive, but slower, particle (correct answer **D**).

Question 23

Many candidates answered this correctly, selecting answer **D**. As the springs are in series, each spring experiences a force of 80 N. The extension can be found by calculating the extension of each spring separately, and then adding the extensions.

Some candidates incorrectly added the two spring constants, and then divided 80 N by this value to calculate the extension of the composite spring, selecting the incorrect answer **A**.

Question 28

Please note that due to a series-specific issue during the live exam series, this question has been discounted. Each candidate's total mark has been multiplied by a weighting factor so that the maximum mark for the question paper remains unchanged.

Question 29

Candidates found this question very difficult. The question gives a distance of 2.0 m between the first and fifth antinodes, so the antinode spacing is 2.0 / 4 = 0.50 m. In a stationary wave, the antinode separation is $\lambda/2$, so the wavelength is 1.0 m (answer **D**).

Question 32

Most candidates answer this correctly, selecting answer **C**. The most popular incorrect answer was **B**, where the candidates knew there was a difference between the quantities but confused the definitions of potential difference and electromotive force.

Question 34

Most candidates correctly selected answer **B**. Some candidates incorrectly thought that $P = V / R$ and so selected the incorrect answer **A**.

Question 35

Please note that due to a series-specific issue during the live exam series, this question has been discounted. Each candidate's total mark has been multiplied by a weighting factor so that the maximum mark for the question paper remains unchanged.

Question 36

Most candidates correctly chose answer **C**, by determining the total charge transferred as $Q = It = 1.5 \times 10^{-9} \times 3 = 4.5 \times 10^{-3}$ C, then correctly dividing by 2e to achieve the number of alpha particles as 1.4×10^{10}. Some candidates thought the charge on an alpha particle was 1e, and so selected incorrect answer **D**, or simply divided the current by 1e to get the incorrect answer **A**.

Question 37

Please note that due to a series-specific issue during the live exam series, this question has been discounted. Each candidate's total mark has been multiplied by a weighting factor so that the maximum mark for the question paper remains unchanged.

PHYSICS

Paper 9702/22
AS Level Structured Questions

Key messages

Candidates should know the definitions required in the syllabus in detail so that their meaning is clear. In particular definitions involving products or ratios should make these ideas explicit. For example acceleration is defined as change in velocity per unit time. Replacing 'per' with 'upon', 'over' or 'by' does not give the same meaning.

Candidates should avoid rounding intermediate answers in a numerical calculation as this can lead to an incorrect final answer. Candidates should keep intermediate values in their calculators or record them to several more significant figures than the final answer. Ideally only once the final answer has been calculated should this value be rounded.

Candidates should explicitly state the subject of any numerical or algebraic equations they use. This is especially important where more than one equation is used in a question, and when equations are stated and then re-arranged. In some questions credit can be gained for correct statements of physical equations, but only where the whole equation is clearly known.

Candidates should consider checking whether their numerical answers have a plausible magnitude, as this check can often show power-of-ten errors or other arithmetic errors that have been made during the calculation.

Candidates are reminded to carefully read the questions and to pay particular attention to the command words used. Credit is not gained for responses that do not address the question asked.

General comments

There was no evidence that candidates where short of time for this examination.

Most candidates showed clear working to support their answers to numerical questions, allowing credit to be gained for good methods even where errors then occur.

Candidates found questions **1(a)**, **2(c)(ii)**, **4(a)(i)**, **6(b)(i)** and **7(b)** relatively straightforward. They found questions **2(c)(i)**, **6(b)(ii)** and **7(c)(ii)** challenging.

Comments on specific questions

Question 1

(a) The majority of candidates correctly identified which of the listed quantities were SI base quantities. There were a small minority that instead gave the SI units for all the quantities listed. This suggests that the question had not been read carefully. Some candidates also included force or energy as a base quantity. Candidates should be aware of the difference between SI quantities and SI base quantities.

(b) The majority of candidates correctly recalled 'power = work / time'. A number made arithmetic errors with the unit of time. A typical error was to give kg m s^{-2} / s and then cancel the s in the denominator to give kg m s^{-1}. A small number of candidates confused the symbol *P* for power with the symbol *P* for pressure and thus stated 'power = force / area'.

(c) Many candidates obtained the correct value for the power. It was common for candidates to make errors in the conversion of the area given in cm^2 to m^2 resulting in a value for power of the wrong magnitude. Some candidates started with an incorrect equation for intensity despite the units for intensity given in the question providing a strong clue to the correct equation.

Question 2

(a) The definition of acceleration was generally given correctly. There were some definitions that were given in ambiguous terms such as 'change in velocity by time' or 'change in velocity over a period of time'. Neither of these clearly express the concept of a ratio. A small number of candidates gave an incorrect definition in terms of 'the rate of change in velocity per unit time' which is acceleration per unit time.

The weakest candidates often put the incorrect definition 'velocity / time'.

(b) Only a small minority of the candidates attempted to solve this part of the question by equating the loss of gravitational potential energy to the increase in kinetic energy of the diver. Instead, most candidates attempted to resolve the initial velocity into horizontal and vertical components. Generally, candidates were able to correctly calculate the vertical component of the velocity as the diver entered the water. Most however gave this value as their final answer, with very few considering the effect of the horizontal component of velocity on the final speed.

(c) (i) This proved challenging for candidates. Most answers incorrectly described the drag force as increasing. There were a few common misconceptions in most answers:

Some candidates thought that the drag force was proportional to pressure and so would increase with depth.

Other candidates confused drag force with upthrust and attempted to reason that the density of the water increased with depth, leading to an increase in upthrust.

Many candidates thought that the speed of the diver would increase until they reached terminal velocity. Some candidates appeared to describe only the variation of the drag force when the diver was in the initial stage of entering the water, rather than after he was in the water and decelerating as specified in the question.

(ii) Most candidates gave the full working required for this question.

(iii) Many candidates gained full credit on this question. Most candidates were able to use 'resultant force = mass × acceleration'. However, many candidates incorrectly calculated the resultant force, failing to account for one of either the upthrust or the drag force. Most candidates correctly stated the direction of the resultant force.

Question 3

(a) (i) Most candidates were able to read the stress from the graph for the given strain and relate stress with the force applied. A significant number made a power of ten error when converting the stress from GPa to Pa resulting in a very large or small value for the force. Candidates are reminded to consider the plausibility of their numerical answers in the context of the question. Another common error was to use an incorrect equation for the cross-sectional area of the wire, for example some candidates attempted to use the formula for the surface area of a sphere. A small number reduced their intermediate answer for the cross-sectional area to two significant figures and this resulted in an inaccurate value of the force in the second significant figure.

(ii) Many candidates were able to give a correct symbol formula for the elastic potential energy in the wire and were able to relate this to the force calculated in **part (ii)**. A significant number of candidates calculated the extension and gave this as the original length. A small number of candidates attempted to use $E = \frac{1}{2}kx^2$, but incorrectly thought that k was equal to the gradient of the graph (confusing a force–extension graph with a stress–strain graph). Candidates who made a power-of-ten error in **part (i)** often ended with values for the original length of the wire in the order of thousands of meters, which should be identifiable as an implausibly long wire in the context of the question.

(b) In most cases, a straight line was drawn from the origin with a gradient larger than that of wire X. Some candidates did not deduce that the gradient of the line needed to be twice that of wire X. A small number of candidates ignored the instruction to draw the line on Fig. 3.2 and instead attempted to draw a graph in the blank space below the question.

Question 4

(a) The majority of candidates gave two correct responses. In a few cases where the correct composition of the alpha particle was not known, candidates were able to apply the conservation laws to the composition of particle Q and so still gain partial credit.

(b) (i) Stronger candidates gave the full principle of the conservation of momentum. A significant number of responses lacked detail. Many omitted that the **total** momentum is conserved and many omitted that this applied to an isolated system. Very occasionally, reference was made to only a single object (instead of a system of objects) having constant momentum.

A small minority of candidates confused the principle of conservation of momentum with either the principle of moments or the principle of conservation of energy.

(ii) Most candidates gave a well-presented solution to this conservation of momentum question. A significant number were unable to link the initial momentum of nucleus P with the momentum of the alpha particle. Some candidates attempted to use the proton numbers of the particles to find their mass, rather than the nucleon numbers.

Question 5

(a) Stronger candidates correctly related the oscillations of a transverse wave to the direction of propagation of the energy. Many knew that 'perpendicular' was relevant to transverse waves but gave ambiguous descriptions of motions that were perpendicular to each other. A significant number gave no reference to either the oscillations of the wave or the direction of the energy propagation, and many made vague references to 'wave motion'. Some candidates offered contradictory responses such as 'the direction of energy transfer is perpendicular to the wave velocity'.

(b) Some candidates correctly identified the infra-red region of the electromagnetic spectrum. All possible regions were offered by candidates, suggesting that a great many candidates were guessing.

(c) Stronger candidates found this straightforward and presented clear solutions. Some candidates confused the electromagnetic wave's period with its wavelength. Others thought that the time-base setting was equal to the period. Many candidates were unable to correctly determine the period from the time base setting and the diagram. Power-of-ten errors and transcription errors were particularly common. Occasionally, the value of the frequency of the wave was rounded up so that the final value of the wavelength was incorrect in the second significant figure. Some candidates did not use the velocity of electromagnetic waves given on the data page, instead using a typical value for the speed of sound in air or attempting to calculate a speed using distance / time.

Question 6

(a) (i) Stronger candidates gave detailed, concise answers.

Many candidates focussed on what was happening at the screen, and neglected to explain that diffraction was occurring at the slits.

A significant number of candidates referred only in general terms to the concept of constructive and destructive interference, such as 'constructive interference gives bright fringes' and did not include sufficient detail in terms of path difference or phase difference.

Candidates were confident in correctly describing 'a bright fringe being formed when waves meet with a phase difference of zero'. Explanations of dark fringes were often vague, such as 'waves meet out of phase', rather than the more precise 'phase difference of 180°'.

Some candidates sometimes demonstrated a misconception that ‘bright fringes are formed where the light waves hit the screen and dark fringes are formed where the light waves have been blocked by the slits’, implying the diffraction pattern is a shadow.

(ii) Most candidates started with the correct equation to determine the wavelength. Stronger candidates were able to correctly calculate the fringe width, whilst some candidates found this challenging. Some candidates used the distance given for six fringe widths as one fringe width, or incorrectly divided this distance by 7 rather than 6. Many candidates correctly converted the distances given to get a final answer in metres.

(iii) Most candidates were able to determine that the new fringe separation would be smaller than the original.

(b) (i) Most candidates gave a correct position for a node. Some candidates drew a cross close to, but not at, the position of a node. Some candidates incorrectly identified the location of an antinode.

(ii) Only the strongest candidates correctly identified that the phase difference would be zero as the wave was stationary. Most candidates guessed the phase difference was 90° or attempted to use a scale drawing to infer the phase difference, perhaps thinking that it was a progressive wave. A few candidates incorrectly suggested the phase difference would be 360°.

(iii) Most candidates gained credit for stating the correct phase difference of 180°.

Question 7

(a) The definition of electric potential difference was given correctly by stronger candidates. A significant number only described the energy transferred with no reference, or only vague reference, to this being in ratio with charge. Many described ‘the energy required to move a unit charge’, again without reference to a ratio. A few candidates gave the equation $V = IR$. Very few candidates confused potential difference with electromotive force.

(b) This was straightforward and well answered by most candidates. Those that did not gain full credit usually applied wrong physics to the circuit. Occasionally, the total circuit resistance (7.2 Ω) was confused with the internal resistance. Some candidates began by calculating an incorrect circuit current of 1.8 V / 6.0 W = 0.30 A, which incorrectly assumes that there is no internal resistance. There were some candidates who considered the internal resistance and the 6 Ω resistance to be connected in parallel.

(c) (i) Stronger candidates found this straightforward. The most common incorrect answer was that the e.m.f. of the cell after t_1 would be greater than it was before t_1. This misconception may stem from the graph showing a greater current after t_1 than before t_1.

(ii) This question proved challenging for all candidates. Some candidates described the variation in current without any reference to resistance and so were unable to gain credit. The majority of candidates correctly explained the variation of one part of the graph but neglected to explain the other parts of the graph.

Few candidates attempted to explain the period of constant current before t_1.

Most candidates were able to explain that the sudden increase in current was due to a decrease in total resistance at t_1. Only the strongest candidates went on to explain the increase in resistance of the lamp due to its increase in temperature, and that this led to the reduction in current over time.

Some candidates who correctly identified that the lamp’s temperature increased then stated that ‘the resistance’ increases, without specifying clearly that the resistance of the lamp increases.

Many candidates throughout their responses referred ambiguously to ‘resistance’ increasing or decreasing, without explicitly describing whether this referred to the resistance of the lamp, the fixed resistor, the internal resistance of the cell, the parallel combination of resistors or the total resistance of the circuit. Candidates are encouraged to be precise in their descriptions.

There were many answers that indicated a lack of understanding of Ohm’s Law.

Question 8

(a) Correctly answered by most candidates. There were a significant number that gave no response or an answer that was an apparent guess.

(b) (i) Correctly answered by most candidates. 'Up' quark was the most common correct answer, but candidates also correctly offered 'charm' and 'top'. A small number of candidates gave two or three quarks as their answer, suggesting that they had not carefully read the question.

(ii) Correctly answered by most candidates, though many mis-spelled 'meson'. Candidates are reminded that syllabus terms must be clearly distinguishable from each other, which is most easily achieved through correct spelling. Some candidates suggested that particle P was a proton or other baryon.

(c) (i) Most candidates identified particle X correctly. A few incorrectly identified X as a positron or gave the ambiguous answer 'beta particle'. As both beta-plus and beta-minus particles are on the syllabus, this answer was not sufficient to gain credit.

(ii) Stronger candidates generally gave a correct answer. Some candidates were unable to apply conservation laws to the β^- decay. Some candidates suggested that the nucleon number would be greater for Q, perhaps confusing nucleon number for neutron number.

(iii) Only some candidates gave a correct answer. Some candidates stated that R would have an extra proton compared to Q but did not explicitly compare the charges.

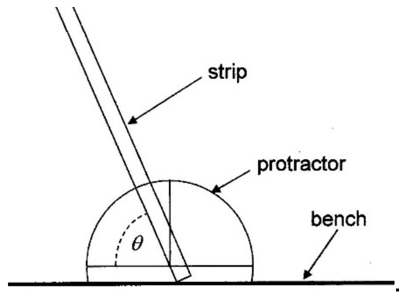
Most candidates did not appear to realise that Q and R are nuclei and so are both positively charged. Instead, many responses seemed to suggest the candidate believed Q and R to be atoms and so assumed that Q would be neutral and R would have a charge of +1(e).

PHYSICS

Paper 9702/33
Advanced Practical Skills

Key messages

- To be successful answering **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. General points such as 'measurements were difficult' or 'use more precise measuring instruments' will not usually gain credit without further detail.
- Often credit is not gained because the description isn't precise or detailed enough. For example, the word 'straight' should not be used instead of 'vertical' or 'horizontal'. The correct word can often be found in the text of the question. Similarly, the word 'board' should not be used when referring to a 'strip'.
- Many candidates thought that the use of a protractor to measure the angle between the bench and a sloping wooden strip could give rise to parallax error, or that it was difficult because the protractor's origin could not be positioned on the bench. In fact neither of these problems was present if the protractor was rested on the bench and against the strip so that its origin coincided with the lower surface of the strip, as shown in the diagram.



General comments

No Centre reported any difficulty in providing the equipment needed.

The values given in the Supervisor's Results and the comments in the Supervisor's Report enabled examiners to allow for any small changes to equipment when assessing candidates' work.

Nearly all candidates completed the two questions.

Many candidates had been well prepared using practice papers, and they demonstrated their skills in measuring, recording and processing their results.

Comments on specific questions

Question 1

(a) In a few cases the unit for *x* or *T* was omitted in **part (i)** or **part (ii)**.

Credit was gained for repeated timings in **part (ii)** and examiners were expecting to see at least two measurements of 5*T* but in many cases this was not recorded.

(b) The majority of results tables were neat and clear and all contained at least six sets of measurements.

Column headings were usually correct, but many candidates were unsure about the unit for $\sqrt{x^3}$ and either omitted it or gave cm^3.

Credit for the range of *x* values used was often not gained because the highest value available was omitted.

Strong candidates gave all their values of *h* to the nearest millimetre but in a few other cases extra zeros were added to each reading or the value was rounded to the nearest cm.

Calculation of the $\sqrt{x^3}$ values was generally done well, but often the number of significant figures given was not correct (for example giving 4 s.f. when *x* only had 2 s.f.).

(c) (i) Graphs were in general clearly presented and accurately plotted, although accuracy could not be checked if large dots were used.

In several cases the choice of axis scales was poor, often with the points compressed into a small part of the grid in the vertical direction because the *T* scale started from zero.

For most candidates the scatter of the points about a linear trend was small enough to gain credit for quality of results.

(ii) The candidate's 'best fit' line could often be improved by rotation, and in some cases the line was not straight.

(iii) Most candidates knew how to calculate the gradient of their line, the only common error being the use of co-ordinates that were too near to each other (they are only credited if they are separated by at least half the length of the line). In most cases coordinates were read accurately, although awkward scales could make this difficult and sometimes led to errors.

In some of the cases where the $\sqrt{x^3}$ axis was not started from zero the candidate made the error of reading the intercept value directly from the vertical axis.

(d) Most candidates transferred their values from **(c)(iii)** correctly when determining *a* and **b**, with only a few cases of using values to just one significant figure or written as fractions.

The unit for *a* was unusual but strong candidates included it correctly in one of several possible formats.

Question 2

(a) (i) Nearly all values given for *L* and d_A were in the expected range, although d_A was often only stated to the nearest centimetre.

(ii) Most candidates' θ_A values fell within the broad range allowed although a few values suggested that the wrong angle was being measured or the wrong protractor scale used.

Examiners were looking for readings to the nearest degree, but in a few cases the angle was recorded to a tenth of a degree.

There was often no evidence of repeated readings being taken.

(iii) Most candidates knew how to work out the percentage uncertainty but many used an absolute uncertainty of only one degree and this was considered unrealistic for this experiment, given that repeated readings were rarely identical.

(iv) The calculation for F_A involved a complex expression and most candidates answered this accurately.

(b) All candidates recorded values for the second strip and most gained credit for the correct trend in their θ_A value compared with the first strip.

(c) Most candidates calculated the two *k* values correctly. Rounding of the answer to only one significant figure was not accepted.

(d) Many candidates correctly calculated the percentage difference (or an equivalent) between the two *k* values, then compared it with the given uncertainty 15 per cent, then stated their conclusion. Some made a mistake in (or omitted) one or more of these steps and did not gain credit.

(e) This part of the question requires candidates to not only identify a difficulty but also link it to the measurement involved. The stronger candidates followed this pattern and gained credit.

Many candidates stated parallax error as a problem and this was credited as long as it was linked to the measurement of d_A or d_B but not if it was linked to the measurement of θ (see Key Messages).

Many expressed concerns about whether the smooth board was vertical and some went on to describe a method of checking that it was.

Unwanted movement of the smooth board was often mentioned, together with suggested improvements to the clamping arrangements.

Stronger candidates pointed out that the mass of the adhesive putty was not considered in the calculation of *F* and went on to suggest either measuring the mass of the putty and including it in the calculation, or using adhesive tape instead.

Achieving consistent 'just sticking' angles for repeated tests was also credited as a problem. Several candidates thought that this was caused by an uneven bench surface and suggested carrying out the experiment on a flatter board placed on the bench.

Other creditworthy responses can be found in the published mark scheme.

PHYSICS

Paper 9702/42
A Level Structured Questions

Key Messages

- 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. This is particularly important for questions that require extended writing. 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.

- 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. Examiners will only consider symbol equations to be part of an answer to a question that asks candidates to define a quantity if the symbols in the equation are defined.

- 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.

- 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 credit.

- Final 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 final answers to too few significant figures, and rounding intermediate answers prematurely, can both lead to full credit not being awarded.

- It would be helpful for candidates to be advised that there is no need to spend time, or to use up answer space, by repeating the question.

General comments

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

There was no evidence that candidates who were properly prepared for the examination had insufficient time in which to complete the paper. There were, however, significant numbers of candidates who did not offer a response to one or more questions. It goes without saying that the lack of a response can never lead to the award of credit, and candidates should be encouraged to offer a response to every question on the paper. Even if the candidate is not confident about the answer, it is always possible that examiners may find opportunities to award credit where a response is present.

Comments on specific questions

Question 1

(a) Many candidates stated that gravitational potential is defined to be zero at infinite separation. However, many candidates were confused between force and energy ideas in attempting to explain the negative sign, and responses in terms of the direction of the gravitational force were common.

(b) (i) Generally well-answered, although some candidates treated the values of $1/r$ as r. The stronger candidates generally realised that the magnitude of the gradient of the line is MG, and provided they were careful with the powers of ten and the substitution of G they were mostly able to show the value of M correctly.

(ii) Most candidates either knew or were able to derive the appropriate starting equation. Various different errors were made in the substitution, including in the unit conversion for the period or forgetting to square the period and/or pi. But many candidates achieved the correct answer.

(iii) Many candidates were able to obtain values for the kinetic and potential energies of the orbit. However, in determining the additional energy needed to move the satellite from orbit to infinity, the common error was to add the kinetic energy to the potential energy needed, rather than to subtract it.

Question 2

(a) Many responses were seen that gave the textbook definition of the internal energy of a system in general, but only the strongest candidates then applied this correctly to the ideal gas system that was the subject of the question.

(b) (i) The overwhelming majority of candidates knew the starting equation $W = p\Delta V$. However, mistakes in applying it to the situation described in the question were frequent. The most common mistake was to treat the value of ΔV given in the question as a final volume and not the change in volume described. Many other candidates did not appreciate that the data in the question required a 3 significant figure answer. A few candidates incorrectly gave the work done by the gas as a negative value.

(ii) Another question that required a 3 significant figure answer. Some candidates struggled to determine the correct final volume, and others applied the proportionality relationship to the centigrade temperature rather than the absolute temperature. Otherwise there were few difficulties, and many candidates obtained the correct final answer.

(iii) A generally well-answered question. The vast majority of candidates knew the equation for specific heat capacity, although some candidates used the final temperature rather than the change in temperature when substituting into it.

(c) A more challenging question aimed at differentiating between stronger candidates. Those that were able to use the correct technical terminology accurately were usually able to gain some credit. It was important to be careful in distinguishing between the thermal energy supply to the system and the change in internal energy of the system; it was common either for the two to be confused or for vague references to just 'energy' to avoid specifying which energy was being discussed.

Candidates are advised that any question asking for an explanation using the first law of thermodynamics will require clear discussion of all three of the terms in the law as they apply to the given scenario.

Question 3

(a) Most candidates knew the correct equation for the total energy of oscillations. A common mistake was to not appreciate that the 14 mm distance given in the question corresponded to four amplitudes. However, candidates who took the amplitude to be either 7 mm or 14 mm were able to gain part-credit.

(b) (i) Many candidates did not realise that, to answer this question, the value of angular frequency needs to be substituted into the defining equation of simple harmonic motion together with a value of acceleration equal to the acceleration of free-fall. Candidates who did this were usually able to achieve full credit.

(ii) The first mark for this question required a clear description of the point in the oscillation where the contact is first lost. Many descriptions were too vague to be awarded credit. A common incorrect answer was one that made reference to 'where the amplitude is a maximum'. These candidates were confused with the notion of resonance as frequency of oscillation is varied, and did not realise either that there is no maximum amplitude in the scenario in the question, or that maximum amplitude is not a description of a position in the oscillation. The second marking point was for the explanation of why the point is at the top of the oscillation, either in terms of the downward acceleration exceeding the acceleration of free-fall or in terms of the contact force just falling to zero.

Question 4

(a) Generally well-answered, with most candidates able to calculate the correct answer.

(b) Most candidates knew the equation for the energy stored in a capacitor. However, a significant number of candidates used a ΔV value in the equation, rather than finding the difference in the two energy values.

(c) (i) Most candidates correctly closed the gaps in the wires and added the capacitor in parallel with the load resistor. A significant number of candidates offered no response.

(ii) The starting point for this question was to read off values of initial and final p.d.s and a time between the two within a single discharge cycle. Candidates who did this and then substituted correctly into the exponential equation were usually able to achieve credit. A large number of candidates used a value of time that spanned more than one discharge cycle and were therefore unable to gain any credit.

(d) **Part (i)** required candidates to appreciate that full-wave rectification does not change the mean power, which is therefore half the peak power. **Part (ii)** required candidates to appreciate that the mean power is halved in half-wave rectification and that therefore the value needs to be halved again from the value in **(i)**. Some candidates achieved both marks, although credit for **part (ii)**, often from the error-carried-forward principle, was more common than credit in **part (i)**. Many candidates attempted spurious application of $\sqrt{2}$ factors, demonstrating a poor understanding of power in alternating current.

Question 5

(a) Many candidates were successful in achieving at least some credit in this question. It was not unusual for weaker candidates to think that 'direction' is a quantity, rather than a property of a quantity. A significant minority of candidates thought that angular velocity varies in circular motion.

(b) (i) Many fully correct derivations were seen here, from candidates who were able to set out their reasoning clearly, a step at a time.

(ii) Generally answered successfully by candidates that knew the mass and charge of an alpha particle. A significant proportion of candidates, however, did not know either or both of these properties.

(iii) Most candidates thought that there was either a direct or inverse relationship between period and radius. Kepler's law was often erroneously applied. Stronger candidates were able to articulate that the period remains unchanged because the equation shows it is independent of radius.

(iv) A significant proportion of candidates did not make the connection between constant velocity and straight-line passage through the region of the fields. As a result, what was intended to be a straightforward application of the velocity selection equation eluded many candidates.

Question 6

(a) (i) Only a minority of candidates realised that flux linkage remains constant with distance along the inside of a solenoid.

(ii) Very few candidates were able to explain the constancy of flux linkage in terms of the magnetic field having a constant flux density inside the solenoid. Many weaker candidates thought this was a question about electromagnetic induction and discussed cutting lines of flux.

(iii) Generally well answered by candidates who knew the equation for magnetic flux linkage. A common mistake was in the power of ten conversion from cm^2 to m^2, with either 10^{-2} or 10^{-6} factors. Some weaker candidates squared the area.

(iv) This question discriminated well between candidates that understood electromagnetic induction and those who did not. A common response from many of the weaker candidates was to replicate the shape of Fig. 6.3 rather than to focus on what the gradient of Fig. 6.3 was doing.

(b) Whilst full credit was rare, it was achieved by some of the strongest candidates, and many other candidates were able to achieve some of the marks available. The most difficult of the three marking points was the one that required a discussion of how the magnetic fields due to adjacent turns interact with each other to cause a force between the turns.

Question 7

(a) Many candidates knew the relationship between energy and momentum of a photon, but some did not calculate the answer to the 3 significant figure precision demanded by the data provided.

(b) (i) Generally well answered by the stronger candidates.

(ii) Candidates needed to appreciate that the starting point to this derivation is the identity of force as rate of change of momentum. From this starting point, many candidates did successfully use the correct relationships between photon energy and photon momentum, and between power and energy, to prove the required formula. There were many starting points seen that were based on incorrect physics, and these were unable to be awarded credit.

(c) (i) Many candidates thought that threshold wavelength is a minimum wavelength, rather than a maximum wavelength. Others thought that the photoelectric effect involves emission of photons rather than electrons from the metal. Candidates who knew their bookwork were usually able to recall the correct definition of threshold wavelength.

(ii) The starting point was to appreciate that the largest wavelength requires the smallest work function. Candidates who chose the correct work function, and correctly applied the eV to J conversion, were usually able to calculate the correct answer.

Question 8

(a) The definition of binding energy was well-known by many candidates.

(b) (i) Generally well-answered.

(ii) The most common mistake by candidates in answering this question was to treat the values in the table as binding energies rather than binding energies per nucleon. Some candidates also thought that a unit conversion was required. Others treated the values in the table as mass defects and attempted to apply the mass-energy equation.

(iii) This was a challenging question, and many candidates gave responses that were along the right lines but not enough to be awarded credit. A common misconception was that the lack of stability was due to there being more neutrons than protons, overlooking the fact that this is true for the vast majority of stable nuclei (including xenon-132).

(iv) Many of the stronger candidates were able to calculate the correct answer of 1.2 s.

Question 9

(a) (i) Well-answered by many candidates.

(ii) Many candidates explained that the metal with the higher melting point is used to avoid it being damaged or needing to be replaced as frequently. Fewer were able to explain why the target gets hot in the first place.

(b) Most candidates knew the general exponential equation for transmitted intensity, but many did not apply it correctly to the whole sample. It was common to see calculations that only dealt with the absorption in either tissue or bone, but not both.

(c) (i) The definition of specific acoustic impedance was generally well-known.

(ii) Many candidates used the intensity reflection equation correctly to determine the percentage reflected as 41 per cent. However, only the stronger candidates realised that this is not the percentage transmitted asked for in the question.

(iii) There was much confusion in this question, and a lack of appreciation of what was being asked. The question asked about the transmitted intensity in the sample as a percentage of the intensity that enters the sample. Responses to do with losses at the air/tissue boundary, losses in air, and issues relating to detection were therefore not relevant to what was being asked. Candidates were expected to observe that the figure calculated in **(c)(ii)** only deals with one bone-tissue boundary, whereas in the sample there are two of these boundaries. They were also expected to comment that there will also be absorption of ultrasound in the bone and tissue itself, further reducing the transmitted intensity.

Question 10

(a) (i) Most candidates were able to substitute correctly into the Stefan-Boltzmann law equation. However, many struggled with the subsequent arithmetic to calculate a value for the radius correct to the required 3 significant figures. The stronger candidates were generally able to give the correct answer.

(ii) Most candidates knew the equation relating luminosity and radiant flux intensity, though some made mistakes with its use. Not squaring the distance, or using the radius as the distance, were common errors. A significant minority of candidates calculated the correct numerical answer but did not know the correct unit for radiant flux intensity.

(iii) Well-answered by many candidates.

(b) (i) Many candidates drew the 5 lines correctly spaced and shifted the correct way.

(ii) Most candidates found this a difficult question, but many of the stronger candidates were able to calculate the correct answer.

(iii) This question was well-answered by many candidates, though a significant minority, whilst giving the correct conclusion, were unable to give a correct explanation.

PHYSICS

Paper 9702/52
Planning, Analysis and Evaluation

Key messages

- In **Question 1**, candidates' responses should include detailed explanations of experimental procedures such as how to control variables, how to take measurements and how to analyse the data.
- The numerical answers towards the end of **Question 2** require candidates to show all their working and for the values to be correctly evaluated with appropriate units. A full understanding of significant figures, and the treatment of uncertainties, is required.
- Candidates need to understand how to use logarithms (both logarithms to base ten and natural logarithms) correctly.
- The practical skills required for this paper should be developed and practised with a 'hands-on' approach throughout the course.

General comments

In **Question 1**, it is advisable that candidates should think carefully about how they would perform the experiment in the laboratory using the points given on the question paper to aid their answer. Planning a few key points before answering **Question 1** is useful. Many candidates experienced difficulties rearranging the proposed relationship into a suitable equation of a straight line, $y = mx + c$ format. It is essential for candidates to have experienced practical work in preparation for answering this question. When describing methods of data collection, credit is rarely available for just quoting equations – a description of measurement of the quantities used in the equation is needed.

In **Question 2**, candidates should be familiar with completing a results table for quantities and their uncertainty, and with finding the gradient and y-intercept of a graph. For several candidates, credit was not awarded because the plotted points were not balanced about the line of best fit or the worst acceptable line did not pass through the error bars correctly or coordinates were wrongly read off when determining the gradient and/or y-intercept.

In question parts requiring mathematical manipulation, stronger candidates clearly stated the equation used with correct substitution of numbers, and then calculated the answer including an appropriate unit. Candidates should be encouraged to set out their working in a logical and readable manner.

Comments on specific questions

Question 1

Most candidates correctly identified the independent (L) and dependent variables (E). Candidates should then consider the control of variables and explicitly state the quantities that need to be kept constant to make the experiment a fair test. In this experiment it was expected that candidates would state that the density of the metal or ρ would be kept constant. Strong candidates tend to use the given symbols rather than attempting to describe the quantities to be kept constant. A clearly defined quantity is required for this mark. Credit is not given for simple stating 'control' ρ since this is just repeating the stem of the question and does not indicate what is meant by 'control'.

Candidates were awarded credit for a clearly labelled diagram. Diagrams should be drawn of the workable experiment. In this experiment, strong candidates drew the rod supported above a bench or surface with appropriate labels. A common error was to place the rod on the bench so that all of it was in contact with the bench. There was also credit for drawing the microphone connected to an oscilloscope. Some candidates correctly drew this connection as a circuit diagram using the correct circuit symbols for a microphone and oscilloscope. Candidates who drew a battery in series with the microphone and oscilloscope or drew a microphone connected to a computer did not gain credit.

Additional credit was awarded to candidates who described a clear method to determine the frequency from the oscilloscope. It was expected that candidates would explain how to determine the period of one wave using the time-base and then how the f could be determined. Many candidates possibly repeated a previous mark scheme and just discussed the use of the horizontal distance rather than referring to one wave. There was also additional credit for describing how to determine an accurate value for the period by adjusting the time-base so that a fewer number of waves appeared on the screen so that the length of one wave was as large as possible.

The common method to measure the independent variable L was to use a metre rule; 'metre scale' did not gain credit.

The density of the metal also needed to be determined. Credit was given for the use of a top-pan balance to measure the mass m of a rod; 'scale' did not gain credit. Additional credit was for measuring the diameter d of the rod using a micrometer or calipers and then explaining how the density was determined in terms of d and m. Some candidates also gained credit for repeating the measurements of diameter along the length of the rod and determining the average value for d. Candidates who incorrectly stated using a micrometer to measure the radius of the rod without stating the measurement of diameter or did not indicate how the volume was determined from the diameter did not gain credit.

Many candidates suggested correct axes for a graph. There were many possible variations. Candidates who found the analysis section straightforward rearranged the equation to make the dependent variable f the subject and then took logarithms. Candidates must explicitly state the quantities to be plotted on each axis either in the text or on drawn axes – credit is not given for just writing $y = mx + c$ under an equation.

Candidates also needed to explain how the graph would confirm the suggested relationship. Candidates need to use the words 'relationship is valid if' and the word 'straight' to describe the line. Some candidates did not gain credit since they incorrectly stated the line would pass through the origin. Stronger candidates often stated the y-intercept that the straight line would pass through if the relationship was valid.

Candidates needed to explain how they would determine values for the constants E and n from the experimental results using the gradient and y-intercept. Candidates needed E and n to be the subjects of the relevant equations, for example, 'gradient = $-n$' or 'use the y-intercept to determine E' did not gain credit. Credit was not awarded to candidates who did not correctly identify appropriate axes for a graph to plot. Some candidates incorrectly rearranged the expression for the y-intercept. Some candidates used 'ln' (indicating the use of natural logarithms) for their axes but then used '10' rather than 'e' when determining E. Examiners assume the use of 'log' represents '$\log_{10}$'.

The additional detail section had a maximum of six marks that could be awarded. Candidates should be encouraged to write their plans including appropriate detail; credit is often gained for describing techniques that candidates have experienced in their practical work. Vague responses were not credited. It is essential that candidates' answers are relevant to the planned experiment rather than describing general 'textbook' methods.

When describing safety precautions, candidates should be encouraged to explain how the precaution proposed is relevant to the experiment as opposed to general laboratory rules. In this experiment, precautions that were relevant to the possibility of the rod falling gained credit. Some candidates discussed the precautions linked to the hammer falling – examiners ignored reference to the hammer, since the hammer should be under the control of the experimenter.

Some candidates included in their answers irrelevant detail which did not gain credit, e.g., the use of ear defenders, keeping the force of the hammer constant when the hammer hits the rod, keeping the distance between the rod and microphone constant.

Other additional detail which gained credit included performing the experiment in a quiet room – soundproof room did not gain credit since it does not prevent other sounds in the room itself. Credit was also given for having a gap between the rod and the microphone to prevent the rod hitting the microphone or for using a cone to increase the sound detected by the microphone. Credit was also gained for waiting until the trace on the oscilloscope was steady.

Some candidates suggested the use of large values of *L* to reduce the uncertainty in the measurement of *L*. There was credit for repeating the measurements of *f* for the same value of *L* and determining the average *f*. Repeating the experiment is not sufficient without further explanation.

Question 2

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

(b) Candidates often calculated the values in the table correctly. Some errors occurred due to incorrect significant figures – often row 2 was written as '5400'. Since I was recorded to three significant figures, values of $1/I$ should have been recorded to three (or four) significant figures. A small number of candidates recorded the values of $1/I$ to five or six significant figures. Other errors were due to incorrect rounding. Most candidates correctly determined the uncertainties in $1/I$.

(c) (i) The points and error bars were straightforward to plot. A common error was incorrectly plotting (5.25, 7140) either horizontally at 5.20 or 5.30 or vertically at 7100. When plotting points, the diameter of each point should be less than half a small square. Candidates need to take greater care over the accuracy of the error bars and ensure that the error bars are symmetrical.

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

(iii) Most candidates clearly demonstrated the points that they used to calculate the gradient. Some candidates misread coordinates or did not use a sensibly sized triangle. A small number of candidates chose data points that did not lie on the lines, often using data from the table that is close to the line instead. Candidates should be encouraged to select two points on the line of best fit which are easy to read, i.e., the points are on grid lines. Strong candidates often included the 10^3 power (from the *x*-axis for kΩ) in their calculations which assisted in the interpretation of the gradient and *y*-intercept in **part (d)**. A significant minority of candidates calculated the gradient as $\Delta x/\Delta y$.

When determining the uncertainty in the gradient, candidates need to show their working, including the coordinates that they have used from the worst acceptable line and how the uncertainty is determined from the gradients of the line of best-fit and the worst acceptable line.

(iv) The majority of the candidates who were awarded full credit set out their working clearly. Stronger candidates often substituted data from the gradient calculation **(c)(iii)** into $y = mx + c$. Some candidates incorrectly read-off the *y*-intercept when $R = 1.0$ (false origin). Other errors seen included candidates incorrectly dividing the *y* value by *mx* or inconsistent use of power of tens between the gradient and the *x*-axis value used.

To determine the uncertainty in the *y*-intercept, strong candidates set out their working clearly, often substituting data from the gradient calculation for the worst acceptable line from **(c)(iii)** into $y = mx + c$. Candidates who just read from the *y*-axis did not gain credit.

(d) (i) Candidates should show the substitution of the gradient and *y*-intercept into correct expressions to determine the values of *E* and *Z*. Credit was not given for substituting data values from the table. Candidates are also expected to give the values of *E* and *Z* to an appropriate number of significant figures with appropriate units which should have the correct power of ten. Common errors included omitting the 10^3 from the *x*-axis of the graph resulting in a power of ten error and incorrect units. Candidates should be encouraged to go back to the beginning of **Question 2** to remind themselves of the meaning of the quantities that are being calculated. It is clear from the question that *E* is electromotive force (e.m.f.) and *Z* is resistance.

(ii) Most candidates added the percentage uncertainty in the gradient to the percentage uncertainty in the *y*-intercept, clearly showing the numbers that are substituted into the equations. Some candidates first calculated a value for the uncertainty in *E* (using the uncertainty in gradient) and then added it to the uncertainty in y-intercept. A clear method needed to be demonstrated. Some candidates determined the percentage uncertainty by maximum and minimum methods. It was essential that either the maximum *y*-intercept and minimum gradient (or the minimum *y*-intercept and maximum gradient) were shown to be used to determine the maximum (or minimum) value of *Z*.

(e) There were different methods that candidates could determine *R.* Some candidates used the gradient and *y*-intercept, while others substituted values for *E* and *Z* from **(d)(i)**. Candidates needed to show clear and logical working for this question as well as considering the power of tens. It was expected that the final answer would be given to at least two significant figures.