PHYSICS

Paper 9702/12
Multiple Choice

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

General comments,

Candidates performed particularly well in **Questions 4**, **5**, **14**, **15**, **20**, **22**, **38** and **39. Questions 8**, **17**, **21**, **30** and **36** were also answered correctly by most candidates. There were no general trends in topic areas that candidates found particularly easy or difficult, with a varied performance in questions across each topic area. However, candidates were more successful in certain types of question than others, with questions involving pure recall or straightforward calculations particularly well answered. Questions that required deeper conceptual insight, perhaps including algebraic or graphical analysis, were more challenging. They found **Questions 6**, **7**, **9**, **10**, **16**, **24**, **31** and **37** particularly challenging.

Comments on specific questions

Question 1

Weaker candidates found this question challenging. The most popular incorrect option was **D**, perhaps because candidates did not recognise the tesla as a unit.

Question 6

Weaker candidates found the analytical demands of this question very challenging, with most of them opting for option **B** (which involved taking 11.0 s as the time spent accelerating). However, stronger candidates found the question relatively straightforward.

Question 7

Candidates found this a challenging question, revealing widespread difficulties in understanding of forces acting on a system. Many candidates chose option **B**, perhaps indicating a misconception that the two forces being compared are related by Newton's third law.

Question 9

This was another question that candidates found challenging, but in this case the main difficulty that they experienced was in distinguishing between options **B** and **C**. Stronger candidates realised that, irrespective of whether the time scale was long enough for terminal speed to be reached (which is unknown in the question), the crucial point was that the gradient of the curve must be equal to the gradient of the initial graph at the point of release.

Question 10

Many candidates found this question challenging with option **B** preferred by some stronger candidates and option **A** chosen by many weaker candidates. These options involved finding, respectively, the initial kinetic energy of the rock and omission of the use of conservation of momentum to determine the final speed of the moving piece.

Question 14

A number of weaker candidates incorrectly chose option **C**.

Question 16

Candidates found this question challenging. Some candidates were distracted by option **D**, which involved using the diagonal distance rather than the vertical height in the potential energy equation. Other candidates chose option **C**, which involved making the same mistake but neglecting to take the power needed to drive the escalator against friction into account.

Question 20

A significant minority of weaker candidates were tempted by option **A.**

Question 23

Weaker candidates found this question difficult, and all four options were chosen.

Question 24

This was challenging for many candidates. Option **A** was a popular choice. The question revealed some confusion between the conditions required for the formation of stationary waves and the respective conditions required for constructive and destructive interference.

Question 31

Many candidates selected option **C**, and candidates did not recognise the need for a deeper analysis, based on evaluating the resistance of each lamp that the information in the question (about the resistances remaining unchanged) was designed to prompt.

Question 33

Many weaker candidates did not take into account the polarity of the cells and so chose option **D**.

Question 37

Only stronger candidates answered this correctly. Option **B** was often chosen by weaker candidates.

PHYSICS

Paper 9702/22
AS Level Structured Questions

Key messages

- It is important that candidates present the steps in their calculations in a clear and logical way. They should explicitly state the subject of any equation. If an equation is rearranged, the new subject should also be stated. This will allow any correct working to be credited even when the final answer is incorrect.
- Candidates should be encouraged to read the command words used in each question carefully. For example, "state and explain" indicates that an explanation is required as part of the answer. In this case it is essential that candidates avoid giving only a statement without any supporting explanation.
- Candidates should use the number of significant figures in the question data as a guide to the number of significant figures required in the final answer. In the vast majority of cases a minimum of two significant figures is appropriate for the final answer.

General comments

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

Many of the questions were answered well but there were other questions that most candidates found to be challenging. Many could have improved their answers to parts of **Question 4** by having a greater understanding of the energy transfers that occur when objects move against resistive forces. In **Question 5(c)**, some candidates had difficulty applying Malus's law. In **Question 6(d)**, many candidates found it difficult to explain the operation of a circuit that contains two batteries connected in parallel.

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

Comments on specific questions

Question 1

(a) Most candidates realised that they could use the homogeneity of the equation given in the question to determine the SI base units of the constant *k*. Weaker candidates sometimes found it difficult to combine the base units of the different quantities. A common error was to leave the unit of force as the newton instead of converting it into base units.

(b) A significant number of candidates did not use the formula for upthrust that was given on the Formulae Sheet. Sometimes the weight of the sphere was substituted into this formula instead of substituting the value of the upthrust. This meant that the density of the sphere was calculated instead of the density of the liquid. Weaker candidates were often unable to recall the correct expression for the volume of a sphere.

(c) (i) The three arrows were usually drawn correctly. The most common error was to draw the arrow representing the viscous force in the downward direction instead of in the upward direction.

(ii) Many candidates found this part of the question challenging. Most did not recognise that when the sphere is falling at terminal velocity, there is zero resultant force acting on it. Therefore, the viscous force can be determined by subtracting the upthrust from the weight. Many candidates incorrectly substituted the value of the upthrust instead of the value of the viscous force into the equation given in the question.

Question 2

(a) Successful candidates understood that the horizontal component of the velocity is constant because there are no horizontal forces acting on the droplet (as air resistance is negligible). Candidates needed to give a precise explanation that distinguished the horizontal motion from the vertical motion. Weaker candidates sometimes explained that there was no resultant force at all acting on the droplet which is incorrect because the resultant force is equal to the weight.

(b) The vast majority of responses were correct.

(c) Stronger candidates were able to consider the vertical motion of the droplet independently from the horizontal motion. Although most candidates attempted to use the relevant equation of uniformly accelerated motion, a common error was to use the initial horizontal velocity ($6.6\ \text{m s}^{-1}$) as the initial vertical velocity.

(d) Most candidates correctly stated that the displacement of the droplet would be less than the distance along its path. However, weaker candidates sometimes did not give a supporting explanation or gave an explanation that was insufficiently precise.

(e) Candidates who had correctly calculated the height in **(c)** were usually able to apply Pythagoras's theorem to determine the total displacement of the droplet from P to Q. Weaker candidates did not understand how to combine the vertical and horizontal displacements.

Question 3

(a) In questions that have the command word "show", it is essential that all the steps of the calculation are clearly and explicitly presented. Most candidates showed satisfactory calculations. However, a significant number of the calculations did not present all the interim steps in a logical order or presented equations without an explicit subject.

(b) (i) The decrease in momentum was usually calculated correctly.

(ii) This question was reasonably well answered, but some weaker candidates did not attempt a response.

(c) Only stronger candidates realised how the magnitude of the horizontal force exerted on the wall by the water could be deduced by applying Newton's third law of motion.

(d) Most candidates recalled the appropriate algebraic expression for calculating the pressure. However, weaker candidates sometimes tried to use the formula for hydrostatic pressure that is given on the Formulae Sheet.

Question 4

(a) Stronger candidates found this question to be straightforward. However, other candidates did not understand the energy transfers in relation to the movement of the child down the slide. Many candidates did not recognise that the kinetic energy gained when there is no resistive force would be equal to the decrease in the gravitational potential energy.

(b) The algebraic formula for kinetic energy was usually stated correctly. However, mistakes were often made when applying this formula to the question as many candidates found it difficult to manipulate the algebra. A significant number of candidates did not attempt a response.

(c) It was expected that candidates would calculate the length of the slide by dividing the work done against the resistive force by the value of the resistive force. Only a minority of candidates were able to calculate the correct value of the work done. The most common mistakes were equating the work done to the kinetic energy at end Y or to the decrease in gravitational potential energy. Many weaker candidates did not attempt this question.

(d) (i) Candidates who could recall the relevant algebraic equations were usually able to apply them correctly. A significant number of weaker candidates made the mistake of equating the maximum compressive force to the maximum elastic potential energy.

(ii) This question was generally answered well.

(iii) Only the strongest candidates were able to sketch a graph to show the correct relationship between the compression of the spring and its elastic potential energy. The most common incorrect graph shape was a straight line through the origin. A significant number of weaker candidates did not give a response.

Question 5

(a) (i) Most candidates stated the need for two waves to have the same frequency or wavelength (and speed). However, many did not describe the requirement for the waves to travel in opposite directions and overlap. Some candidates incorrectly stated that the waves should be in phase.

(ii) Only stronger candidates correctly stated that the phase difference would be zero. The most common incorrect answer was 180°.

(b) (i) Almost all candidates tried to apply the Doppler effect formula given on the Formulae Sheet. A significant number of candidates made mistakes when substituting the data into this algebraic formula. The value of the observed frequency was often inappropriately substituted as the source frequency. Many candidates did not give their answer to three significant figures as instructed in the question.

(ii) Most candidates did not understand the qualitative relationship between the variation in the observed frequency and the variation in the speed of the motorcycle. Although the strongest candidates realised that the speed would be decreasing, many others guessed that it would be increasing or constant.

(c) (i) Malus's law was usually applied correctly to determine the ratio of the transmitted intensity to the incident intensity of the light. However, arithmetic errors were often made when using this ratio of intensities to calculate the ratio of the amplitudes.

(ii) Only a small proportion of answers were correct. There was a wide variety of incorrect answers, with many candidates stating an angle of 180° or 70°.

Question 6

(a) (i) The vast majority of answers were correct.

(ii) Most candidates showed a correct calculation of the charge that passes through the resistance wire. Weaker candidates often had difficulty in using this charge to determine the number of free electrons.

(iii) This question was usually answered correctly

(b) Most candidates could recall the relevant algebraic equation. A significant number had difficulty in converting the value of the cross-sectional area from units of mm^2 to units of m^2.

(c) It was usually understood that the larger diameter of the second wire would result in a smaller resistance. A common misconception was that a smaller resistance would cause less power to be dissipated in the wire. This reasoning did not take into account that there would also be a larger current which would then lead to more power being dissipated.

(d) Most candidates were unable to use Kirchhoff's second law to deduce that there would be the same potential difference across the wire. Therefore, the current and the power dissipated in the wire are unchanged. The most common misconception was that the potential difference across the wire would increase and that this would then lead to an increase in current and an increase in power.

Question 7

(a) (i) This was usually answered correctly. A significant number of candidates misspelt the word "neutrino". The most common incorrect answer was "antineutrino".

(ii) Most candidates answered this correctly. Some candidates gave incorrect answers that corresponded to the emission of a β^- particle instead of a β^+ particle. Others incorrectly believed that the nucleon number was equal to the number of neutrons in the nucleus.

(iii) Many weaker candidates incorrectly thought that a down quark would change to an up quark.

(b) (i) Those candidates who knew that a baryon consists of three quarks were usually able to determine the correct charge of each quark. Weaker candidates often simply guessed a value of the charge of each quark. Common incorrect answers included $-\frac{1}{3}e$ and $+\frac{2}{3}e$.

(ii) There were three possible correct flavours. Stronger candidates tended to choose antiup quarks, but many realised that anticharm or antitop quarks were other correct alternatives. Weaker candidates often just guessed an incorrect flavour or did not attempt a response.

PHYSICS

Paper 9702/33
Advanced Practical Skills 1

Key messages

- Where a set of readings is being produced, candidates should consider the largest and smallest values that are possible (within the limitations of the apparatus) and then ensure that they include a reading close to each of them.
- When adding the best fit straight line to a graph, a 15 cm ruler will almost always lead to a join and often a kink. It is far better for candidates to use a transparent 30 cm ruler.

General comments

Many candidates were well prepared for the practical paper and this was demonstrated in their measuring and processing of results. Nearly all candidates completed the two questions.

Very few centres reported difficulty in providing the equipment needed.

Comments on specific questions

Question 1

(a) (i) Most values recorded for F were in the expected range but in a few cases were slightly high, suggesting that candidates had not waited long enough for the oil to run down the tube before adding more.

(ii) All candidates recorded values for the water column heights a and b. In a few cases a unit was not included.

In some cases when calculating the difference y, an extra zero was incorrectly added, e.g. 28.6 – 23.5 = 5.10 cm.

(b) There were many neat, clear tables of results and nearly all candidates included six sets of readings. Most column headings included a correct unit. All values in the table should have been recorded to the nearest millimetre but in a few cases some values were only recorded to the nearest centimetre. For many candidates the range of h values was too small to gain credit.

(c) (i) The standard of graphs was generally good. It was usually possible to fit the data in this question onto the graph grid using simple scales. In a few cases candidates used very awkward interval values. This appeared to be an attempt to use the entire graph grid. It is only necessary for the points to occupy at least half of the large squares in each direction.

Plotting of points was usually accurate, but in a few cases the plots were too large (heavy crosses or large dots) and this meant that accuracy could not be checked.

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

(ii) Candidates' best fit line could often have been improved by rotation, and in many cases a kinked line was drawn.

(iii) Most candidates knew how to calculate the gradient of their line. The only common error was the use of co-ordinates that were too near to each other. Credit was awarded only if they were separated by at least half the length of the line. In most cases coordinates were read accurately, but awkward scales sometimes made this difficult and led to errors. Use of values from the table of results was only accepted if they lay on the candidates' line.

(d) Many candidates correctly transferred their values from **(c)(iii)**, with only a few cases of using values to just one significant figure.

The units for *a* and *b* were sometimes omitted, but when they were included, they were usually correct.

(e) Most candidates calculated the oil density successfully but a few missed a unit or used an incorrect one (e.g. g / cm^3).

Question 2

(a) (i) Since this was a hand-rolled ball of clay, its diameter would vary. Most candidates recorded a diameter value to the nearest millimetre, but many didn't record repeat readings

(ii) The precision of the measuring instrument (a ruler) was 1 millimetre, but the uncertainty was greater than this due to parallax error and variation in diameter. An uncertainty in the range 2 to 5 mm was expected, which was then converted to a percentage.

(b) Most candidates recorded that there was one spring above the clay but some candidates counted the number of coils in the spring and recorded that as their *n* value.

Some candidates had difficulty in determining the period *T* of the oscillations. One problem seemed to be that half cycles were counted rather than a complete cycles. In a few cases the time taken for the oscillations to die away was measured instead of the period of one oscillation.

(c) Nearly all candidates recorded their second set of measurements after reducing the quantity of clay and changing its position. In some cases the diameter of the new sphere indicated that the removal of a quarter of the clay had not been carried out carefully.

(d) (i) Most candidates calculated the two *k* values correctly. There were some cases of arithmetical error or incorrect rearrangement of the expression. Rounding of the answer to only one significant figure was not accepted as the measured values used had at least two significant figures.

(ii) Stronger candidates stated that their choice of significant figures for *k* was determined by the significant figures in both *d* and *T*. Reference to raw readings was not accepted.

(e) Many candidates answered this question well and knew they had to check whether the percentage difference between the two *k* values was less than the maximum 20 per cent uncertainty specified in the question before stating their conclusion. The mistake of referring to the percentage difference as percentage uncertainty was ignored if working clearly showed what had been calculated.

(f) (i) This section called for descriptions of difficulties found in carrying out the procedures, and limitations in the accuracy of readings. Stronger candidates gave good, clear answers with sufficient detail and linked each limitation to a particular measurement. Many candidates identified the problem of verifying a relationship with only two sets of test data. The irregular shape of the hand-rolled sphere was often identified as well as the risk of parallax error when measuring the diameter with a ruler. Another concern was the measurement of *T*. The period was short, making it difficult to judge the ends of the oscillations or even to count them. Some candidates described the difficulty in attaching the clay without it restricting the movement of some of the spring coils.

(ii) Links to specific problems listed in **(i)** needed to be clearly stated with the relevant improvement given. Many candidates stated that taking more readings and plotting a graph could be used to test the suggested relationship.

The use of callipers for measuring *d* was often suggested and accepted as a way to avoid parallax error.

The idea of recording a video of the experiment (with the stop-watch in view) and then playing it in slow motion to judge *T* was another common improvement, though the term “slow-motion camera” was not credited.

Some candidates who were concerned about using modelling clay as the mass suggested using metal masses instead but didn’t include enough detail about its attachment.

PHYSICS

Paper 9702/42
A Level Structured Questions

Key messages

- Where quantities are changing, candidates must correctly identify these changes as increases or decreases, rather than just stating that the quantity changes. This was relevant to **Questions 2(d)(ii)** and **8(b)(iv)**.
- In "show that" calculations, all constants must be seen as numerical values in the substitution line. This was relevant to **Questions 1(c)(ii)** and **12(d)**.
- Candidates should take care to avoid ambiguous wording. For example, in **Question 11(b)(i)** two anti-particles are not necessarily a particle and its anti-particle.
- When an expression is to be derived, candidates' final line needs to be a quote of the required expression.

General comments

Most candidates who were well prepared appeared to have a good understanding of the new topics in the syllabus and were able to respond successfully to the questions relating to them.

Candidates should be reminded that they must answer the question as it has been set rather than similar questions that have appeared in other papers. They should also be guided by the precision of the data in the question in deciding how many significant figures to give the answer to. Candidates were also required to give units with answers for some calculations and they should ensure they have a good knowledge of the units of all quantities contained in the syllabus.

Comments on specific questions

Question 1

(a) This question was generally answered well but some candidates did not take sufficient care to ensure that the lines drawn were actually radial. Some candidates did draw radial lines but then contradicted this response by also drawing concentric circles. The weakest candidates drew the arrows pointing in the incorrect direction or drew lines of equipotential (concentric circles).

(b) Only stronger candidates answered fully correctly but many gave at least one of the points being looked for. It was common to see responses in which gravitational and centripetal forces were discussed as being different forces that somehow balance each other out. Only a few candidates recognised that the force had to have a constant magnitude and just stating that the force was constant does not convey this meaning.

(c) (i) This derivation was answered well. Since the graph had angular velocity on one of the axes, it was much easier to use this as the start point. Candidates needed to make sure they reached the expected expression as the final line of their derivation.

(ii) Most candidates answered this correctly. Candidates who did not substitute in all values including the numerical values of constants did not gain full credit in this "show that" calculation. This also applied to the use of the powers of ten in the substitution or calculation of the gradient as well.

(iii) Most candidates either achieved the correct answer or did not seem to know where to start. There was also some confusion between speed (linear velocity) and angular velocity. The most common error was to neglect to square root at the end and give the value of speed^2 instead of speed.

Question 2

(a) Only weaker candidates found this question challenging.

(b) This calculation proved to be straightforward and was answered correctly by most candidates.

(c) Many candidates completed the table correctly and gained full credit here.

(d) (i) The most common cause of error was carelessness over specifying the directions of the changes with reference to the system. Some candidates gave both directions and some gave no indication of the direction of the change at all.

(ii) Stronger candidates scored full credit by logically linking each pair of points together but in some cases the logic of the answer and the linking of the statements together was not as clear. Weaker candidates referred to changes rather than increases or decreases and gained no credit.

Question 3

(a) This question was answered well. However, candidates should be encouraged to use the terms weight or gravitational force, rather than gravity.

(b) Many candidates gave explanations of why upthrust is upwards, rather than explanations of why the resultant force is upwards. A common misconception was an incorrect reference to Newton's Third Law, and an explanation of upwards resultant force as a necessarily equal and opposite response to the downwards push.

(c) (i) There were many good definitions of simple harmonic motion, but very few candidates related this to the stated force equation. The significance of the constant values and the minus sign were often omitted.

(ii) This proof was completed well by many candidates.

(d) (i) Many candidates discussed either damping / loss of energy and resistive / viscous forces, but only a minority did both. Some candidates thought the greater upthrust in the lowest position was the cause of the difference in displacements.

(ii) Many candidates scored at least partial credit here. However, a common error was the use of just one of the amplitudes rather than both to find the difference in energies.

Question 4

(a) The majority of candidates made no reference to force and so gained no credit on this question. The error made by many candidates was to refer to the direction of the field rather than the force due to the field.

(b) (i) Most candidates did not know how to start, which was by setting up the equation equating potentials. Those who did set up the equation correctly, usually went on to calculate the correct answer. Errors were introduced due to the signs of the charges or by just using one equation of potential energy with both charges included in one expression.

(ii) This question proved to be challenging and only stronger candidates discussed the directions of the fields.

(iii) Only stronger candidates answered this correctly. Candidates needed to determine the direction of the force on the electron and its relative magnitude due to each of the charges P and Q and then their resultant.

Question 5

(a) This question was generally answered well by candidates who knew either the equation for energy stored in a capacitor or that the energy is the area under the Q–V graph. A significant number of candidates unfortunately missed the information in the question that the p.d. across the capacitor is 8 V, and instead worked their answers using a p.d. of 12 V.

(b) (i) This question was usually answered correctly. The most common reason for not gaining full credit was missing out where the value of the capacitance had come from, which is necessary in a "show that" question.

(ii) Only the very strongest candidates answered this correctly, with most candidates forgetting that energy is proportional to V^2 and attempting to apply the general exponential decay equation incorrectly using *x* as the energy stored.

(c) There were some very good answers here, but many candidates did not use the fact that the capacitance was doubled rather than just increased and therefore the time constant was also doubled.

Question 6

(a) Most candidates answered this correctly.

(b) This was answered correctly by most candidates but some reversed the answers to **(a)** and **(b)**.

(c) (i) Lenz's law was quoted well by stronger candidates. This most common omission was the reference to the direction of the induced e.m.f.

(ii) Candidates found applying the laws of electromagnetic induction to this situation challenging. It was important to refer to locations within the system, for example, the change of flux linkage was in the smaller solenoid, the (induced) current was in the smaller solenoid. However, the majority of candidates managed to gain at least partial credit for their explanation.

Question 7

(a) (i) This question was generally answered well.

(ii) There were many correct answers here, but some plus signs were not on an output wire and sometimes there was more than one plus sign added, which was a contradiction.

(b) (i) A significant number of candidates just quoted the general ac formula with no specific values given for V and ω. Candidates failed to apply the data in the question to the general equation.

(ii) Many candidates showed a lack of understanding of the difference between peak and r.m.s. values here. Peak power was a common answer instead of mean power.

Question 8

(a) This question was answered well.

(b) (i) Many candidates were unable to give the correct name for the phenomenon shown. The most common incorrect response was the photoelectric effect.

(ii) Many candidates realised the wave behaviour of electrons was being shown, but very few added that this was only true for moving electrons. A significant number of candidates thought that electron diffraction provides evidence for both the wave and the particle nature of electrons.

(iii) Only the strongest candidates were able to achieve credit for relating the interatomic spacing in the crystal to the de Broglie wavelength of the electron beam.

(iv) This question was more successfully answered, with many candidates realising that the decreased wavelength of the beam must mean the accelerating p.d. had been increased.

Question 9

(a) This question was answered correctly by most candidates.

(b) (i) There were many correct answers here, but some candidates used a half-life of 0.6 s, i.e. half of the maximum time shown on the time axis on Fig. 9.1.

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

(iii) There were many accurate sketches seen but some were less carefully drawn. Several candidates completely misunderstood what was happening and some candidates gave no answer.

(c) (i) Many candidates were able to determine the number of nuclei that had decayed. Some candidates made errors in the conversion of electron-volts to joules.

(ii) Some candidates realised that emission of gamma photons and the kinetic energy of the recoiling lead nucleus accounted for the difference in energies, but many candidates incorrectly thought this was something to do with the random nature of radioactive decay.

Question 10

(a) Most candidates gained credit for the correct formula here. However, common errors were to omit the efficiency altogether, or to use 5 per cent instead of 95 per cent, or to omit the power of ten conversions of g and ms. Some candidates conflated the Q in $Q = mc\Delta T$ with the Q in $Q = It$.

(b) Most candidates knew the starting equation here, but confusion between transmission and absorption often led to errors.

(c) Candidates often referred to the magnitude of an individual μ value rather than comparing the differences. Some answers simply stated which image had good / poor contrast without explaining why.

Question 11

(a) Many candidates missed either the idea of the tracer being radioactive or the fact that it was placed in the body.

(b) (i) Explanations of annihilation usually contained some of the elements needed, but only stronger candidates gave all of them. The idea of a particle meeting its own antiparticle, with the result that all of their mass is converted into energy was required. The most common omission was the reference to mass. There was poor use of the terms particle and antiparticle, with references to "2 particles" or "2 anti-particles" meeting. There was also vague reference to collisions resulting in the release of energy, seemingly oblivious to the fact that there are many other nuclear and chemical processes for which this is the case that are not annihilation processes.

(ii) This question was generally answered well.

(c) (i) This straightforward calculation was completed well.

(ii) The most common error here was the omission of the factor of two because two gamma photons are formed.

(d) There were some excellent descriptions of how the detection of the gamma photons is used in PET scanning to form the image. There was sometimes confusion with other imaging techniques, for example CT scanning.

Question 12

(a) This question required candidates to define luminosity as the total radiant power of the star. Some candidates omitted the key word "total" and others confused power with energy or intensity. Elsewhere candidates referred just to "light" rather than all EM radiation.

(b) Most candidates knew the starting equation here, but many did not know the unit or did not recognise that the 3 significant figure data in the question justified a 3 significant figure (SF) answer. Some candidates calculated a 3SF answer, with the correct unit, but only used a value of distance correct to 2SF and so obtained an incorrect answer.

(c) This calculation was competed well, but a significant minority of candidates used the radiant flux intensity at the Earth in **(b)** rather than the luminosity of the Sun.

(d) This "show that" calculation was correctly completed by most candidates. However, some candidates did not substitute all numerical values, including those of constants.

(e) Here, errors occurred when candidates used an incorrect starting equation (leading to no credit) or started with the correct equation but applied it incorrectly (leading to partial credit). This was another question where 3SF data should have been recognised as justifying a 3SF answer.

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.
- Candidates need to understand how to use a single light gate connected to an appropriate device to determine quantities such as velocity and acceleration.
- 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.
- The practical skills required for this paper should be developed and practised with a 'hands-on' approach throughout the course.

General comments

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

In **Question 2**, candidates should be familiar with completing a results table for quantities and their uncertainty, and with finding the gradient of a graph. For several candidates, credit was not awarded because the points were not plotted correctly, the line of best fit or worst acceptable line was not drawn correctly or coordinates were wrongly read off. In question parts requiring mathematical manipulation, stronger candidates clearly stated the equation used with correct substitution of numbers, and then calculated the answer and unit. Candidates also need to understand the method by which the uncertainty is determined when measurements are repeated. Candidates should be encouraged to set out their working in a logical and readable manner. Care should be taken when numbers are crossed out.

Comments on specific questions

Question 1

Most candidates correctly identified the independent and dependent variables. Candidates should then consider the control of variables and to 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 *d* would be kept constant. There was an additional credit for also stating that *B* and *m* would be kept constant. Some good candidates gained further credit by explaining a method to keep *d* constant for example by marking the sheet at the start point. Credit was not scored for vague answers in terms of 'keeping distance constant' – it is expected that the quantity should either be the symbol defined in the question or clearly defined in words.

Candidates were awarded credit for a clearly labelled diagram. Diagrams should be drawn of the workable experiment. In this experiment, candidates needed to support the sheet using a clamp and stand on a bench or a jack. Resting the sheet against a wall did not gain credit. Candidates also needed to indicate the position of a light gate at point X. It was difficult to draw but good candidates often added dashed lines and labelled point X.

Candidates also needed to indicate that the light gate was connected to a timer or data logger. To determine the velocity at X using a single light gate, candidates needed to state that the beam would be interrupted. Some good candidates discussed adding a card of length L and then determining v by the relationship L / t. A large number of candidates used two lights – one at the start and one at X and then stated incorrectly that $v = d / t$ – which would be the average velocity that the trolley had between the start at point X as opposed to the velocity at point X.

Most candidates used a protractor to measure θ. Good candidates gained an additional detail mark for drawing the protractor on the diagram in the correct position. A few candidates explained how the angles may be determined using trigonometry with a correct relationship to determine θ. Good candidates used clearly indicated the distances on the diagram.

Many candidates also gained credit for stating that distance d would be measured using a rule. Credit was not given for '*using a rule to measure distance*' since the distance was not defined. Candidates also needed to explain how m and B could be determined. Most candidates correctly stated the use of a top-pan balance for m. A large number of candidates correctly suggested the use of a Hall probe to determine B. There were some good explanations of rotating the probe until the maximum reading was obtained and also for repeating the measurement of B in the opposite direction and calculating the average value.

Many candidates suggested correct axes for a graph (often v^2 against $\sin\theta$). A significant number of candidates incorrectly suggested plotting v against θ. Candidates must explicitly state the quantities to be plotted on each axis either in the text or on drawn axes – credit is not given for just writing $y = mx + c$ under an expression. An additional detail mark was available for candidates 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. Credit was not given to candidates who stated the line should pass through the origin.

Candidates needed to explain how they would determine values of p and q from the experimental results using the gradient and y-intercept. Candidates needed the constants p and q to be the subject of the relevant equations. Credit was not awarded to candidates who did not correctly identify appropriate axes to plot.

The additional detail section had a maximum of six marks that could be awarded. Candidates should be encouraged to write their plans including appropriate detail; some candidates' answers suggested that they did not have sufficient practical experience. Vague responses were not credited. It is essential that candidates' answers are relevant to the experiment in question rather than general 'textbook' rules for working in the laboratory. When describing safety precautions, candidates should be encouraged to explain how the precaution proposed is relevant to the experiment. In this experiment a sensible precaution was to have a cushion or block after the trolley to stop the trolley on the bench. Credit was not given for suggestions of cushion on the floor since it would be better to prevent the falling of the trolley.

Question 2

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

(b) Most candidates were able to calculate values for $\frac{1}{R}$ / $10^{-3}\,\Omega^{-1}$and tan θ correctly. A common error was that candidates did not use an appropriate number of significant figures for ln (R / s^{-1}). Since θ was recorded to three significant figures, values of θ should have been recorded to three (or four) significant figures. The majority of candidates determined the absolute uncertainty in $\frac{1}{R}$ correctly.

(c) (i) The points and error bars were straightforward to plot. When plotting points, the diameter of each point should be less than half a small square. The plotted points must also be less than one small square. For example, a few candidates who plotted '25.6' on the $\frac{1}{R}$ axis at 25.0 (left had grid line) did not score credit. 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 point since the plotted points would not be balanced. 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. Candidates should be encouraged to take into account the powers of ten in the quantities.

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

(d) Most candidates calculated the mean value of frequency, but a significant number of candidates did not determine the absolute uncertainty correctly. From repeated values, the absolute uncertainty should be determined by finding half the range.

(e) (i) Candidates should show the substitution of the gradient to determine the value of *C*. Credit was not given for substituting data values from the table to determine *C*. Candidates are also expected to give the final values of *C* with an appropriate unit which should have the correct power of ten. Many candidates omitted to allow for the 10^{-3} from the *x*-axis of the graph for the values of $\frac{1}{R}$.

(ii) Most candidates added the percentage uncertainty in the frequency to the percentage uncertainty in the gradient, clearly showing the numbers that are substituted into the equations. Some candidates determined the percentage uncertainty by maximum and minimum methods. It was essential that either the maximum frequency and maximum gradient (or the minimum frequency and minimum gradient) were shown to be used to determine the minimum (or maximum) value of *C*.

(f) There were two methods that candidates could use to determine *R*. Some candidates used the gradient, while others substituted values for *C* and *f* from **(e)(i)**. Candidates needed to show clear and logical working for this question. It was expected that the final answer would be given to a minimum of two significant figures.

To determine the absolute uncertainty, the method needed to be consistent with the determination of *R*. Again, clear substitution of the numbers was needed for this mark to be gained.