PHYSICS

Paper 9702/11
Multiple Choice

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

General Comments

This multiple choice paper is set on the AS part of the syllabus. With 40 questions to be answered within the time limit of an hour, accurate and quick working is essential. Candidates must know that they should not spend too long on any one question. Many questions need written working if candidates are to maintain accuracy, and space is provided on the paper for this.

Candidates found this paper difficult. Several questions had a proportion of correct answers in the range 20-30% and this may suggest that the candidates were guessing.

The candidates found the subject area of electricity to be particularly difficult, and would benefit from further practice solving questions on electricity. Candidates should also be encouraged to take particular care when reading values from graphs; it is important to look at the label of the axis as well as the numbers to ensure that power-of-ten or unit errors are not made.

Comments on Specific Questions

Question 3

This question was found to be the most difficult on the paper. Generally speaking people tend to think of 100 °C as hot and 200 °C is therefore very hot. In normal lighting conditions a metal will not be seen to glow until it is over 700 °C so a red-hot ring is at around a temperature of 800 °C. Nearly half of the candidates thought that 200 °C was correct and many gave 100 °C as the temperature.

Question 4

Many candidates did not recognise displacement as a vector or thought that kinetic energy was a vector.

Question 8

Many candidates who did not obtain the correct answer looked at the numbers here and ignored the units, which led them to choose **C**. Candidates should be encouraged to check what is plotted on each axis.

Question 10

The answers were very evenly spread amongst all four options. The lack of air resistance on the Moon needed to be taken into account to get the correct answer **C**.

Question 13

Both masses are being accelerated, so the total mass being accelerated here is 3 kg not 2 kg.

Question 17

Many candidates thought that there must be a force acting in the direction of movement to keep the object going. These candidates thought **A** was the correct answer. If there is no acceleration, there is no resultant force. Only one of the triangles, **C**, shows a resultant force of zero.

Question 21

A common incorrect answer was **C**. Candidates must use $g = 9.81\,\text{m s}^{-2}$ and not $10\,\text{m s}^{-2}$.

Question 22

Many candidates chose **B**, thinking that ice must be denser than water and that the molecules in ice at 0 °C travel more slowly than those in water at 0 °C. Ice floats on water at 0 °C, so it is less dense than water.

Question 26

Answer **C**, showing half the amplitude, was popular. If the intensity is halved, then the amplitude is reduced by a factor of $\sqrt{2}$ rather than by a factor of 2.

Question 27

C was a popular incorrect answer. Candidates need to be familiar with the components of the electromagnetic spectrum, and should have realised that only the electron in this list is not an electromagnetic wave.

Question 34

If current is constant, then power is proportional to voltage and therefore **D** is correct. Many candidates chose **A** but the resistance of component Q decreases as V increases, so Q cannot be a filament lamp.

PHYSICS

Paper 9702/12
Multiple Choice

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

General Comments

The final five questions on the paper were found to be difficult, and it is possible that candidates did not have time to complete these questions, having spent too long on questions earlier in the paper. With 40 questions to be answered within the time limit of an hour, accurate and quick working is essential. Candidates must know that they should not spend too long on any one question. Many questions need written working if candidates are to maintain accuracy, and space is provided on the paper for this.

Candidates should be encouraged to take particular care with the accurate use of prefixes on units and powers of ten.

Comments on Specific Questions

Question 5

Many candidates misread the question and selected **A**. A balance and micrometer would not enable the student to calculate the volume of the wire. Candidates should ensure they read the question carefully, particularly when a critical word is given in bold.

Question 6

A is correct as it shows no random error but a systematic error with the line not going through *p*. **B** was popular but it shows random error without systematic error.

Question 10

Candidates found this question difficult. The most popular choice was **C**, but the speed of the jumper does not reach zero at the top of the flight as he still has horizontal velocity.

Question 11

Many candidates answered this question without looking at the units. This led them to choose the incorrect answer **B**.

Question 12

A large proportion of the candidates treated momentum as a scalar and chose **C**. The change in momentum is $10\,\text{kg}\,\text{m}\,\text{s}^{-1}$ giving a force of 100 N.

Question 16

There is no viscous force on a stationary object, so **D** is correct. Many candidates chose **A**, showing a confusion between upthrust and viscous force.

Question 19

Candidates choosing an incorrect answer had not properly taken units into account.

Question 23

Candidates found this question difficult. Ice floats on water at 0 °C, so it is less dense than water and its molecules must be on average further apart than those in water. At a fixed temperature all the molecules, whether in ice or water, have the same average speed.

Question 26

Both of these wires break at the same force. They have identical diameters so they both have the same ultimate tensile stress.

Question 27

Candidates would benefit from working out an answer on paper when answering this type of question.

Question 30

There are four maxima on each side and one zero-order maximum, so the answer is **D**.

Question 31

A popular incorrect answer was **B**, but 2.5 MHz is nowhere near the microwave region (wavelength 120 m).

Question 33

Answer **A** was given by many candidates. Although the force on an alpha particle is twice that on a proton, the mass of the alpha particle is four times that of the proton, and this makes **C** correct.

Question 34

The key to sorting out this question is in realising that, when the two wires are connected in series, the current must be the same in both. The extra resistance of X then makes its I^2R term twice that for Y. Answer **B** was popular, but X and Y are made from the same material so they must have the same resistivity.

Question 36

A large number of candidates gave the answer as 400 W. This is only true for the first half of the cycle.

Question 39

A common incorrect answer was **A**. Each α-decay reduces the number of nucleons in the material by 4, but does not change the number of atoms.

PHYSICS

Paper 9702/13
Multiple Choice

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

General Comments

This multiple choice paper is set on the AS part of the syllabus. With 40 questions to be answered within the time limit of an hour, accurate and quick working is essential. Candidates must know that they should not spend too long on any one question. Many questions need written working if candidates are to maintain accuracy, and space is provided on the paper for this.

The most difficult questions on the paper were **21**, **28** and **33**.

Comments on Specific Questions

Question 10

A number of candidates thought that **B** was the correct answer here. Velocity is the rate of change of displacement, so it must be zero when the gradient of the displacement-time graph is zero.

Question 11

Less than half of the candidates found **B** as the correct answer. The other options were chosen nearly equally.

Question 12

A large number of candidates did not recognise a change in momentum here. Momentum is a vector and hence the change in momentum is 2*mv*.

Question 15

Candidates who were incorrect did not recognise 'upthrust' as being the result of the density of air, but instead just an upward force. The upthrust is constant. The viscous force is the drag force of the air and this increases until a constant speed is reached with zero resultant force. This is answer **D**.

Question 17

Three forces can only be in equilibrium if they all pass through the same point, otherwise there will be a turning force on the object. The correct answer **A** perhaps looked too familiar to candidates so many chose **B** or **C**.

Question 21

Candidates found this question difficult. The kinetic energy cannot increase as the pipe is sealed and full of water, and it is stated that the water flows at constant rate along the pipe. The water is gaining elastic potential energy as its pressure increases between X and Y.

Question 22

This was a question where common misconceptions surface. The average speed of the water molecules is determined by temperature. Therefore both ice and water molecules at 0 °C will be travelling at the same average speed. **A** is the correct answer, not **B**.

Question 25

Many candidates omitted the factor of 2 arising from the two cables. Candidates should be encouraged to read the question carefully.

Question 26

Many candidates thought that the distance between two nodes is equal to the wavelength, and obtained answer **C**.

Question 28

Estimating sizes is something candidates generally find difficult. All four options to this question were nearly equally popular. In options **B**, **C** and **D** there is a huge mismatch in size between the wavelength and the obstacle.

Question 33

Candidates could have benefited from sketching a diagram. The stretched wire must have ¼ the area of cross-section and therefore 4 times the length. The resistance is therefore 16 times greater.

Question 38

Many candidates chose answer **C**. The 2 mm lead sheet will stop alpha and beta radiation, but will not stop gamma radiation. There is no radiation detected behind the sheet, so there is no gamma radiation.

PHYSICS

Paper 9702/21
AS Structured Questions

Key Messages

- Candidates should always be encouraged to explain their working. Some questions specifically state that working should be shown. Credit is lost quite frequently through a failure to give any explanation whatsoever to accompany numerical working.
- Candidates should be advised not write out large portions of the question when introducing their answers. This is very wasteful of valuable time.
- Candidates should be advised to use the data given on page 2 of the question paper. In particular, the use of the approximation $g = 10\,\text{m}\,\text{s}^{-2}$ should be discouraged.

General Comments

There was no real evidence from any of the candidates of a shortage of time.

There were many scripts where the total mark was very low. Candidates should be encouraged to develop a thorough knowledge of the basic requirements outlined in the syllabus. This knowledge is a foundation for the candidates to gain credit. There were large sections of many of the questions where the vast majority of the candidates made little or no attempt.

There were many examples where the candidate did not give an answer that was linked to the key command words (e.g. 'state', 'explain') in the question. The answer given then failed to answer the question.

Comments on Specific Questions

Question 1

(a) (i) The definition of acceleration was only stated in the acceptable form by a minority of candidates.

(ii) The required statement was given by a very small number of candidates.

(b) (i) The majority of answers were correct. There were a surprising number of candidates who misread the graph or did not know the method of obtaining the distance travelled from a speed against time graph.

(ii) The majority of answers did not relate to the question. Candidates tended to describe the variation of the speed with time as shown on the graph rather than explain the variation in the resultant force as asked in the question.

(iii) Candidates often tried to explain the reasons for the changes in the frictional force rather than just describing the changes, and so would have benefited from more careful reading of the question.

(iv) A significant number obtained the correct answer for the acceleration. The majority of candidates did not consider the resultant force to be the frictional force minus the weight when using $F = ma$.

Question 2

(a) The definition of resistance was given by a small minority of candidates.

(b) (i) The circuit diagrams were generally of poor quality. Many had no meters or the voltmeter was placed in series with an ammeter. There were very few circuits that included any means of varying the current in the circuit such as a rheostat.

(ii) A very small minority were able to distinguish between systematic and random uncertainties.

(iii) Very few candidates realised that the graph showed a systematic uncertainty in the ammeter readings and hence they did not make a correct calculation of the resistance.

(c) The correct value for the resistance was calculated by a significant number of candidates. The calculation of the uncertainty in R was not calculated correctly by the vast majority. A very small number were able to state the value for R with a correct number of significant figures determined by the uncertainty value.

Question 3

(a) The definition was given by only the well prepared candidates.

(b) The majority of candidates were unable to explain the basic theory of how molecules of a gas produce a pressure.

(c) (i) There were a number of correct answers. A surprising number were unable to link the mass and density of the liquid or confused mass and weight.

(ii) Candidates generally completed this part correctly if they had the answer for **(c)(i)**.

(iii) Most candidates could not give an adequate answer.

Question 4

(a) The majority of candidates were unable to describe the diffraction of light as it passes through the elements of a diffraction grating.

(b) (i) The principle of superposition was not described adequately by the majority of candidates. The explanation of the production of maxima with white light required a description of the relation between the path difference and the wavelengths of red and blue light. Very few candidates were able to give a suitable explanation.

(ii) A minority of candidates were able to use an expression related to a diffraction grating. Very few were able to differentiate between the number of lines and the spacing between adjacent slits.

(iii) A wavelength in the visible part of the spectrum was given by very few candidates.

Question 5

(a) The explanation of plastic deformation was given by a very small number of candidates.

(b) (i) A significant number of candidates gave the correct answer.

(ii) A significant number of adequately prepared candidates determined the correct answer.

(c) Very few candidates realised that the use of the Young modulus was only appropriate where the force was proportional to the extension.

Question 6

(a) There were very few completely correct answers as a result of not reading the question carefully. Candidates were asked to describe the atom. The majority that gave suitable answers generally only stated the number of protons and neutrons in the nucleus with little or no description of the atom.

(b) (i) The limited range of α-particles in air was not considered by the vast majority of candidates as a reason for evacuating the apparatus used for the deflection of such particles.

(ii) The majority of candidates were not adequately prepared for describing and explaining the readings obtained in this experiment, and would have benefited from further study of this part of the syllabus.

(c) The link between the current and the charge on the α-particles was not given by the vast majority of candidates. The majority of candidates did not produce an answer.

PHYSICS

Paper 9702/22
AS Structured Questions

Key Messages

- Candidates should always be encouraged to explain their working. Some questions specifically state that working should be shown. Credit is lost quite frequently through a failure to give any explanation whatsoever to accompany numerical working.
- Candidates should be advised not write out large portions of the question when introducing their answers. This is very wasteful of valuable time.
- Candidates should be advised to use the data given on page 2 of the question paper. In particular, the use of the approximation $g = 10\,\text{m}\,\text{s}^{-2}$ should be discouraged.

General Comments

There was no real evidence from any of the candidates of a shortage of time.

There were many scripts where the total mark was very low. Candidates should be encouraged to develop a thorough knowledge of the basic requirements outlined in the syllabus. This knowledge is a foundation for the candidates to gain credit.

There were many examples where the candidate did not give an answer that was linked to the key command words (e.g. 'state', 'explain') in the question. The answer given then failed to answer the question.

Comments on Specific Questions

Question 1

The question was well answered by the adequately prepared candidates.

(a) The majority of candidates obtained at least one mark. The answers from some of the candidates were poorly presented and the working was difficult to follow.

(b) (i) The correct answer was given by the majority of candidates. A significant number either drew a curve or an attempted straight line without a ruler to an incorrect speed.

(ii) A straightforward question that caused little difficulty for the majority of candidates. A small number of candidates lost credit for using $g = 10\,\text{m}\,\text{s}^{-2}$ rather than the value of $9.81\,\text{m}\,\text{s}^{-2}$ given on page 2 of the question paper.

(c) (i) Many answers did not relate the two forces acting on the raindrop when it is falling at terminal velocity. Some answers gave weight – drag = *ma* but did not indicate that in this situation the acceleration is zero.

(ii)1. This question was generally well answered. There were a number of candidates who did not present all the steps in their calculation. In a 'show that' calculation, all steps in the derivation must be explicitly stated.

(ii)2. The majority of sketches were incorrect. The initial section that was meant to be a smooth curve with a gradually decreasing gradient was often poorly drawn or given as a straight line. The horizontal section was frequently not drawn at $7\,\text{m}\,\text{s}^{-1}$. The point between the curve and the

horizontal section was drawn with an abrupt change of gradient. A significant number of candidates tried to draw a separate sketch in the space on page 5 rather than follow the instructions to draw a sketch on Fig. 1.1.

Question 2

The majority of candidates found this question difficult.

(a) There were many answers that are unacceptable at this level, such as 'force is proportional to acceleration' or 'force equals mass × acceleration'.

(b) (i) The majority of candidates either subtracted the two speeds or calculated the rate of change of momentum. The vector nature of momentum was ignored by many candidates who did not include the change in direction and failed to add the two speeds.

(ii) The correct answer was only obtained by the very strong candidates. Some achieved a mark through error carried forward from **(b)(i)**. A significant number made errors with powers of ten either with the time or the mass or both.

(c) (i)1. The majority of answers lacked the necessary precision. The question asked for an answer in terms of the collision between the ball and the wall. Often the answer given was generalised and therefore did not answer the question. Many candidates gave action being equal to reaction. This statement is not acceptable at this level.

(i)2. The answers given were generally very poor with little or no reference being made to momentum changes of the ball and the wall or how these were related. A statement of the law of conservation of momentum did not, on its own, answer the question.

(ii) The correct answer with a reason was given by the majority of candidates.

Question 3

This question was poorly answered by the majority of candidates.

(a) The candidates who read the question carefully generally scored some marks. A common error was to discuss the spacing, bonding or movement of the atoms rather than their arrangement.

(b) The sketch for the metal was generally correct. Only a minority of candidates were able to give a correct sketch for the polymer.

Question 4

Candidates were generally able to score at least half marks on this question.

(a) The majority of candidates only scored the first mark. The well prepared candidates went on to describe the two waves in the tube travelling in opposite directions. Very few described the resulting stationary waves being due to interference of these two waves.

(b) (i)1. A significant number of candidates described the motion correctly.

(i)2. A very small minority of candidates gave the correct answer for the motion of the particles as back and forth along the tube.

There were many statements that did not answer the question such as 'zero displacement' or 'node' and 'maximum amplitude' or 'antinode'.

(ii) The majority of candidates calculated the wavelength correctly and in many cases the subsequent analysis was also correct. A significant number did not know the relationship between the length of the tube and the wavelength of the stationary wave shown in Fig. 4.2.

Question 5

This question was generally well answered and many candidates scored a majority of the marks available.

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

(ii) There were many correct answers.

(iii) The more able candidates scored all three marks. Misconceptions meant that some candidates only scored the mark for the expression of power. These candidates often had equal currents in both branches of the circuit or gave the current in one of the branches as the current from the power supply.

(b) This part of the question effectively differentiated the candidates. The weaker candidates treated the two sections AC and AD as being in parallel or only calculated the potential difference across AC or AD. In general the presentation was poor and hence partial credit was difficult to award when the final answer was incorrect.

Question 6

(a) The vast majority of answers were correct.

(b) The majority of candidates showed the full working and gained full credit. There was some use of $g = 10\,\text{m s}^{-2}$ and this was one cause of lost credit. Those who did not show the calculation of the force acting did not answer this 'show that' question properly.

(c) (i) Very few were able to name two forces acting on the mass. A significant number gave the tension force that acts on the spring. There were other references to air resistance even though the mass was stationary.

(ii) The majority of candidates considered only the force from the spring when calculating the acceleration of the mass. The effect of the weight of the mass was ignored even though it had been used in **(b)** and stated in **(c)(i)**. Candidates should be encouraged to consider the resultant force for F when using the equation $F = ma$.

(d) There were very few correct answers. The majority appeared not to have read the question carefully. Very few differentiated between elastic potential energy and gravitational potential energy. Candidates gave the energy changes from R to S instead of S to R. Others considered the mass to be stationary when it returned to R. Many of the answers suggested that there was only an interchange between kinetic energy and gravitational potential energy. The descriptions were seldom given an explanation as asked for in the question.

Question 7

(a) This part was generally answered correctly. A significant minority made errors by ignoring the factor of 2 for the proton or left the question blank.

(b) There were only a few candidates who described the meaning of isotopes with reference to nuclei. Even fewer referred to the nuclear equation given in the question. The majority who scored any marks gained just one mark for the reference to atoms having the same number of protons but a different number of neutrons.

(c) A significant number of candidates scored one mark. The conservation of energy-mass was given by more candidates than on previous papers. Many candidates did not score this mark as there was a suggestion that energy and mass were both conserved.

(d) (i) This was generally poorly answered with many guesses or no answer given.

(ii) A statement that referred to the products having kinetic energy was mentioned by very few candidates.

(e) The calculation was completed by only the able candidates. Some strong candidates made a power of ten error or used an incorrect conversion factor for the charge on an electron. Many were unable to convert the 13.8 MeV into joule.

PHYSICS

Paper 9702/23
AS Structured Questions

Key Messages

- Candidates should always be encouraged to explain their working. Some questions specifically state that working should be shown. Credit is lost quite frequently through a failure to give any explanation whatsoever to accompany numerical working.
- Candidates should be advised not write out large portions of the question when introducing their answers. This is very wasteful of valuable time.
- Candidates should be advised to use the data given on page 2 of the question paper. In particular, the use of the approximation $g = 10\,\text{m}\,\text{s}^{-2}$ should be discouraged.

General Comments

There was no real evidence amongst adequately prepared candidates of a shortage of time.

As is often the situation, there are many scripts where the total mark scored was very low. Candidates should be encouraged to develop a sound knowledge of the basic work outlined in the syllabus. Such knowledge is the foundation for being awarded credit.

Comments on Specific Questions

Question 1

(a) Generally, the correct answer was given.

(b) Where a candidate did not give the correct answer in **(a)**, then usually an incorrect response was also given in **(b)**.

(c) Most answers were correct, with the answer being given, appropriately, as a decimal to two or three significant figures.

(d) The majority of answers were correct but a surprisingly large number included either work or distance as a vector, omitting weight.

(e) Many diagrams were drawn without careful thought as to direction. In these situations, an arrow was drawn to the right of the centre line at highly inappropriate angles. Conversely, there was a minority of carefully-drawn scale diagrams. The cosine formula was used correctly in a minority of scripts. Where candidates attempted to calculate two perpendicular components for the resultant velocity of the aircraft, many failed to apply correctly the components of the wind speed.

Question 2

(a) (i) It was very common to find that candidates thought that the acceleration would increase from A to B and then decrease from B to C, rather than display constant acceleration and constant deceleration. Despite the instruction to *describe and explain*, most answers were restricted to a description. Few made reference to the equal magnitudes of the acceleration and deceleration as a result of the component of the weight of M down the slope.

(ii) There were some correct responses but many indicated an acceleration of *g* down a slope of length 0.26 m.

(iii) This calculation could be completed successfully either by considering motion down the incline or by using energy changes for a vertical fall of 0.26 m. There were many answers based on incorrect working in **(a)(ii)** that were given credit.

(b) Candidates were expected to explain their working. Where some explanation was given, this was frequently inadequate, being a statement of conservation of energy. Candidates were expected to appreciate that the gravitational potential energy would be the same before and after the motion. Hence, the block would rise to the same vertical height of 0.26 m.

Question 3

(a) In such definitions, it is necessary that the nature of the ratio is made clear. Candidates should be advised that *power* does involve a transfer of energy and therefore, defining power as being 'energy/time' is not appropriate. For both the numerator and the denominator of the expression, the *change* in each quantity should be shown.

(b) (i) Candidates do need to gain experience as to the interpretation of such graphs. In many instances, statements were limited to a discussion of the gradient of the graph. It was expected that the reduction in the magnitude of the acceleration would be related to resultant force and hence to the resistive forces.

(ii) Most answers did include appropriate working. However, explanation was lacking in many.

(iii) Where a tangent is to be drawn, then care needs to be taken to ensure that the line drawn is, by eye, acceptable. There were many instances where the 'tangent' cut the curve or did not touch it at the relevant point. It was pleasing to note that there were few instances where the graph-grid was not read correctly.

(iv) In some answers, the driving force was confused with the weight of the cyclist and, in others, the force was calculated as the product of mass and the acceleration determined in **(b)(ii)**. Most candidates did, however, attempt to relate driving force to resistance and resultant force.

(v) Despite being instructed to use answers from previous parts, there were many answers which did not include any form of numerical analysis. Candidates were expected to relate resistance to speed at 12 m s^{-1} and at 8 m s^{-1}, and hence come to a valid conclusion.

Question 4

(a) Many statements were based on general statements as regards e.m.f. and potential difference. Consequently, there were many references to 'other forms of energy', rather than energy changes relevant to the given circuit.

(b) Answers to this part were generally satisfactory. It was not necessary for current to be the subject of the equation.

(c) (i) There were numerous instances where the e.m.f. was given as 6.0 V, rather than 5.8 V.

(ii) A minority of candidates confused the external resistance with the internal resistance. The majority did, however, use the graph correctly to determine the internal resistance.

(d) (i) This calculation was completed successfully by most candidates.

(ii) The number of correct responses was in a minority. The usual mistake was to divide the answer in **(d)(i)** by that in **(b)(i).** This is clearly incorrect and should have been recognised as such. A pure number cannot be provided by dividing a power by an e.m.f.

Question 5

(a) Answers were, in general, satisfactory although a significant number stated that the speed of $3.0 \times 10^8\,m\,s^{-1}$ in a vacuum is the distinguishing property rather than the fact that the waves can travel in a vacuum.

(b) (i) Candidates could either answer this part correctly or there was much guesswork. However, it was expected that α-particles and β-particles would not be included in the list.

(ii) With very few exceptions, this calculation was completed successfully.

(c) The answers for the meaning of *polarisation* were not of a high standard. Candidates need to distinguish clearly between vibrations in one plane and vibrations in one direction in a plane.

Question 6

(a) (i) In most cases, the particle was identified as being an electron.

(ii) A significant number of answers were based on a comparison with α-particles and γ-radiation, rather than stating properties themselves. It was common to find an answer based, incorrectly, on β-particles having a unique value of either energy or speed.

(b) A significant number of candidates were unaware of the notation for a β-particle.

(c) This calculation presented very few problems for well-prepared candidates, with the major fault being arithmetical errors.

(d) There were very few completely correct answers, as a result of not reading the question carefully. Candidates were asked to describe differences between atoms. With very few exceptions, a definition of the meaning of isotopes was provided.

PHYSICS

Paper 9702/31
Advanced Practical Skills 1

Key messages

- The Supervisor's Report and the sample set of results provided by each Centre form an important part of the marking process, and candidates may be disadvantaged if either is missing. The Supervisor's Report should include details of any difficulties or apparatus changes during the examination so that allowance can be made when marking. If help is provided to candidates, the Supervisor's Report **MUST** include candidate numbers and details of the assistance given.

- Candidates should aim to make graphical work as clear as possible, with scales chosen to make finding points and interpreting gradient read-offs easy. Candidates should be discouraged from making the points fill the whole grid by using awkward scales, e.g. 0.57 : 1. All that is required is that the points occupy at least half of each axis, and a sensible scale, e.g. 10 : 1 or 4 : 1 or 0.5 : 1, can always be found to achieve this.

- Common causes of lost credit in graph work are plotting 'blobs' (points with diameter greater than half a small square) and drawing thick or kinked lines of best fit. Using a sharp pencil and a transparent 30 cm ruler makes it much easier to plot points accurately and draw a good line of best fit.

- Candidates should always think about the precision of their recorded measurements. These should be to the smallest division of the measuring equipment used (e.g. 0.1 cm for a ruler, 0.01 mm for a micrometer, etc.) and no more. This precision should be shown even when the experimenter can select his/her own values (so lengths of wire of exactly 20 cm and 30 cm should be recorded as 20.0 cm and 30.0 cm when measured with a ruler).

General comments

The general standard of the work done by the candidates was good, similar to last year, with a reasonable range of marks.

The majority of Centres had no problem in providing the equipment required for use by candidates. Any deviation between the requested equipment and that provided to the candidates should be written down in the Supervisor's Report, and this report must be sent with the scripts to Cambridge so that the Examiners can take this into consideration during the marking period. Experiments are designed with the view that Centres will have the apparatus as outlined in the syllabus available for use. Any help given to the candidate should be noted on the Supervisor's Report. Supervisors are reminded that under **no circumstances** should help be given with the recording of results, graphical work or analysis.

Candidates did not seem to be short of time and both questions were attempted. Most candidates were confident in the generation and handling of data but once again can improve by giving more thought to the critical evaluation of experiments.

There were no common misinterpretations of the rubric.

Comments on specific questions

Question 1

In this question, candidates were required to investigate how the extension of a spring depends on the load applied to it.

Successful collection of data

(b) (ii) Most candidates measured and recorded the length L within the allowed range of 2.0 – 8.0 cm

(b) (iii) Most candidates measured and recorded the angle between the strip and the vertical line of the protractor to be less than 90° with an appropriate unit of degrees.

(c) Most candidates were able to set up the experiment without assistance and collect five sets of values for L, m and θ.

Range and distribution of marks

(c) Many candidates did not extend a range of readings of m less than 100 g and greater than 350 g. Candidates should be encouraged to consider the largest and smallest values that they can obtain with the equipment provided.

Presentation of data and observations

Table

(c) Many candidates were able to include correct units with the column headings including $m \sin\theta$ / kg. Some candidates wrote the column heading $m \sin\theta$ omitting a unit or a separating mark between the heading and unit. A few candidates omitted the $m \sin\theta$ column completely. Many candidates correctly stated the raw values of L to the nearest mm. Other candidates needed to take account of the precision of the metre rule, having incorrectly recorded their answers to the nearest cm instead of to the nearest mm. Many candidates were able to give the significant figures in the calculated quantity $m \sin\theta$ to the same or one more than the least number of significant figures used for the corresponding raw values of m and θ. Many candidates were able to calculate $m \sin\theta$ correctly.

Graph

(d) (i) Candidates were required to plot a graph of L against $m \sin\theta$. Some candidates gained credit for drawing appropriate axes with labels and sensible scales. Others chose awkward scales that were linear (going up in threes or sixes) or non-linear. Candidates can improve by checking that the first and last points, when plotted, extend over at least six large squares on the grid in the vertical direction and four large squares in the horizontal direction. Many candidates were able to gain credit for plotting the tabulated readings to within half a small square. A sharp pencil is essential for this. Some candidates can improve by drawing plotted points so that the diameter is equal to, or less than, half a small square—which, again, is much easier with a sharp pencil. Some candidates tabulated more than five values but plotted only five, losing credit. Many candidates rounded down their values in the table and plotted the points to one or two significant figures, which again lost credit.

(d) (ii) Some candidates were able to draw a good line of best fit through five points. If a point is being treated as anomalous for the purposes of drawing the best line, this should be indicated clearly on the graph (it is recommended that any anomalous point be checked by repeating the measurement using the apparatus). Some candidates needed to rotate lines to give a better fit or move lines sideways to give a better balance of points along the entire length of the line. Others needed to draw a line of best fit that best represented all of the data, rather than either choosing a few points that lie on a line or using the first and the last point regardless of the distribution of the other points.

Analysis, conclusions and evaluation

Interpretation of graph

(d) (iii) Many candidates used a suitably large triangle to calculate the gradient, gaining credit for the read-offs, and substituted into $\Delta y/\Delta x$ to find the gradient. Other candidates need to check that the read-offs used are within half a small square of the best fit line drawn, show the substitution clearly into $\Delta y/\Delta x$ (not $\Delta x/\Delta y$) and check that their triangle for calculating the gradient is large enough (the hypotenuse should be at least half the length of the line drawn and can be longer). A few candidates drew a suitable triangle but then proceeded to state different read-offs, either from the

table or from different points on the graph that were not on the line of best fit. Some candidates read off the *y*-intercept at *x* = 0 directly from the graph, gaining credit. Others needed to check that the *x*-axis starts with *x* = 0 (i.e. no false origin) for this method of finding the *y*-intercept to be valid. Many candidates substituted a read-off into *y=mx+c* successfully to determine the *y*-intercept. Others needed to check that the point was actually on the line of best fit and not just in the table.

Drawing conclusions

(e) Most candidates recognised that *P* was equal to the value of the gradient and *Q* was equal to the value of the intercept calculated in **(d)(iii)** for the first mark. Others tried to calculate *P* and *Q* by first substituting values into the given equation and then solving simultaneous equations. No credit was given for this as the question specifically asks for the answers in **(d)(iii)** to be used to determine *P* and *Q*. Stronger candidates obtained values of *P* and *Q* with appropriate units. Others needed to include units with the answer, which can be deduced from the units used in the graph scales or from the equation given in **(e)**.

Question 2

In this question, candidates were required to investigate how the motion of a rule depends on its mass.

Successful collection of data

(a) (ii) Most candidates recorded a value of circumference to the nearest mm in the range 30.0 – 50.0 cm. A few candidates incorrectly gave a raw value to the nearest cm when the ruler can be read to the nearest mm.

(a) (iv) Most candidates were able to produce a second loop whose circumference was within 2 cm of the circumference of the first loop.

(b) (ii) Most candidates measured and recorded a value of time for a complete swing *T* for the half-metre rule on the bottom to a precision of 0.1 or 0.01 s. However, many candidates did not repeat their readings of time.

(c) (i) Most candidates recorded a second value of *T* with the metre rule on the bottom.

(ii) Most candidates recorded a new value of *T* with the 30 cm ruler on the bottom.

Quality

(c) (i) Many candidates found that the longer metre rule on the bottom took a greater time to complete a full swing compared with the time with the half-metre rule on the bottom.

Presentation of data and observations

Display of calculation and reasoning

(d) (ii) Many candidates were able to calculate *k* from *T*/*m* for the three different rules. Some candidates confused which time was associated with each rule.

(d) (iii) Many candidates were able to relate the number of significant figures in *k* to time (*t* or *T*) and *m* gaining credit. Other candidates related to just one quantity or to the "raw data" without specifying the quantities used, or to "the quantity with the least number of significant figures" without stating the quantities involved.

Analysis, conclusions and evaluation

(d) (iv) Few candidates compared the percentage difference in their values of *k* by testing it against a specified percentage uncertainty, either taken from **(a)(iii)** or estimated themselves. Candidates should be encouraged to state what they think is a sensible limit for the percentage uncertainty for this particular experiment. Answers such as "the difference in the two k values is very large/quite small" are insufficient.

Estimating uncertainties in the circumference

(a) (iii) Most candidates were familiar with the equation for calculating percentage uncertainty, though very few made a realistic estimate of the absolute uncertainty (2 – 6 mm). Most candidates stated the uncertainty as 1 mm, the smallest reading on the ruler. Candidates should remember that the absolute uncertainty in the value of the circumference depends not only on the precision of the measuring instrument being used, but also on the nature of the experiment itself. Where measurements have been repeated, an acceptable method to estimate the absolute uncertainty is to calculate half the range of the results obtained earlier and use this as the absolute uncertainty.

Evaluation

(e) Many candidates found this section difficult. The key to this section is for candidates to identify genuine problems associated with setting up this experiment and in obtaining readings. An answer such as "it is difficult to measure time" is insufficient to gain credit without an explanation.

Candidates can improve their answers by stating the difficulties encountered during the experiment, e.g. "the loops were not the same size so the rules were not horizontal". Candidates are encouraged to suggest detailed practical solutions that either improve technique or give more reliable data. They can improve their answers by stating the methods used for each solution e.g. use Blu-Tack to fix the string to the rule to prevent the strings moving closer together during the oscillation. In doing this candidates should look at how each solution helps this particular experiment.

Credit is not given for suggestions that should be carried out anyway, such as repeating measurements and calculating averages or avoiding parallax errors by looking at the ruler perpendicular to the scale. Vague answers such as "turn fans off" or "use an assistant" are not usually valid.

A table giving details of limitations and potential improvements can be found in the mark scheme, together with some answers that did not receive credit.

PHYSICS

Paper 9702/33
Advanced Practical Skills 1

Key messages

- The Supervisor's Report and the sample set of results provided by each Centre form an important part of the marking process, and candidates may be disadvantaged if either is missing. The Supervisor's Report should include details of any difficulties or apparatus changes during the examination so that allowance can be made when marking. If help is provided to candidates, the Supervisor's Report **MUST** include candidate numbers and details of the assistance given.

- Candidates should aim to make graphical work as clear as possible, with scales chosen to make finding points and interpreting gradient read-offs easy. Candidates should be discouraged from making the points fill the whole grid by using awkward scales, e.g. 0.57 : 1. All that is required is that the points occupy at least half of each axis, and a sensible scale, e.g. 10 : 1 or 4 : 1 or 0.5 : 1, can always be found to achieve this.

- Common causes of lost credit in graph work are plotting 'blobs' (points with diameter greater than half a small square) and drawing thick or kinked lines of best fit. Using a sharp pencil and a transparent 30 cm ruler makes it much easier to plot points accurately and draw a good line of best fit.

- Candidates should always think about the precision of their recorded measurements. These should be to the smallest division of the measuring equipment used (e.g. 0.1 cm for a ruler, 0.01 mm for a micrometer, etc.) and no more. This precision should be shown even when the experimenter can select his/her own values (so lengths of wire of exactly 20 cm and 30 cm should be recorded as 20.0 cm and 30.0 cm when measured with a ruler).

General comments

The general standard of the work done by the candidates was good and similar to last year.

The majority of Centres had no problem in providing the equipment required for use by candidates. Any deviation between the requested equipment and that provided to the candidates should be written down in the Supervisor's Report, and this report must be sent with the scripts to Cambridge so that the Examiners can take this into consideration during the marking period. Experiments are designed with the view that Centres will have the apparatus as outlined in the syllabus available for use. Any help given to the candidate should be noted on the Supervisor's Report. Supervisors are reminded that under **no circumstances** should help be given with the recording of results, graphical work or analysis.

Candidates did not seem to be short of time and both questions were attempted. Most candidates were confident in the generation and handling of data but could improve by giving more thought to the critical evaluation of experiments.

There were no common misinterpretations of the rubric.

Comments on specific questions

Question 1

In this question, candidates were required to investigate how the motion of a thin card shape depends on where the shape is supported.

Successful collection of data

(b) (ii) Most candidates measured the distance *h* within the allowed range of 0.0850 – 0.095 m. A few candidates needed to take account of the units given on the answer line as an answer of 9 m is unrealistic.

(c) Many candidates recorded the time for several swings and found the time for one swing in the range 0.6 – 1.5 s. Some candidates omitted a unit or stated an answer greater than 1.5 s suggesting that they forgot to divide the recorded time by the number of swings to get the time taken for one complete swing. Other candidates stated a value below 0.6 s suggesting that they timed half a complete swing.

(d) Most candidates were able to set up the experiment without assistance and collect six sets of values for *h* and *T.*

Range and distribution of marks

(d) Many candidates did not extend the range of readings of *h* over at least 15.5 cm. Candidates could have made better use of the available range of holes provided. Some candidates started at hole 9 and adjusted the pendulum either up or down failing to extend their range over all the holes provided.

Presentation of data and observations

Table

(d) Many candidates were able to include correct units with the column headings including h^2/m^2 and $T^2h/\text{s}^2\,\text{m}$. Some candidates wrote the column heading h^2 or T^2h omitting a unit or omitting a separating mark between the heading and unit. A few candidates omitted the T^2h column. Many candidates correctly stated the raw values of *h* to the nearest mm; others needed to take account of the precision of the metre rule, recording answers to the nearest mm instead of to the nearest cm. Many candidates were able to record the calculated quantity h^2 to the same number or one more significant figures as in the corresponding values of *h.* Many candidates were able to calculate T^2h correctly. Some weaker candidates calculated Th^2 , T^2h^2 or Th instead.

Graph

(e) (i) Candidates were required to plot a graph of T^2h against h^2. Some candidates gained credit for drawing appropriate axes with labels and sensible scales. Others chose awkward scales that were linear (going up in threes or sixes) or non-linear. Candidates can improve by checking that the first and last points, when plotted, extend over at least six large squares on the grid in the vertical direction and four large squares in the horizontal direction. Many candidates were able to gain credit for plotting the tabulated readings to within half a small square. A sharp pencil is essential for this. Some candidates can improve by drawing plotted points so that the diameter is equal to, or less than, half a small square—which, again, is much easier with a sharp pencil. Some candidates lost credit by tabulating more than six values but then plotting just six. Many candidates rounded down their values in the table and plotted the points to one or two significant figures, again losing credit.

(e) (ii) Some candidates were able to draw a good line of best fit through six points. If a point is being treated as anomalous for the purposes of drawing the best line, this should be indicated clearly on the graph (it is recommended that any anomalous point be checked by repeating the measurement using the apparatus). Some candidates needed to rotate lines to give a better fit or move lines sideways to give a better balance of points along the entire length of the line. Others needed to draw a line of best fit that best represented all of the data, rather than either choosing a few points that lie on a line or using the first and the last point regardless of the distribution of the other points.

Analysis, conclusions and evaluation

Interpretation of graph

(e) (iii) Many candidates used a suitably large triangle to calculate the gradient, gaining credit for the read-offs, and substituted into $\Delta y/\Delta x$ to find the gradient. Other candidates need to check that the read-offs used are within half a small square of the best fit line drawn, show the substitution clearly into $\Delta y/\Delta x$ (not $\Delta x/\Delta y$) and check that their triangle for calculating the gradient is large enough (the hypotenuse should be at least half the length of the line drawn and can be longer). A few candidates drew a suitable triangle but then proceeded to state different read-offs, either from the table or from different points on the graph that were not on the line of best fit. Some candidates read off the *y*-intercept at $x = 0$ directly from the graph, gaining credit. Others needed to check that the *x*-axis starts with $x = 0$ (i.e. no false origin) for this method of finding the *y*-intercept to be valid. Many candidates substituted a read-off into $y=mx+c$ successfully to determine the *y*-intercept. Others needed to check that the point was actually on the line of best fit and not just in the table.

Drawing conclusions

(f) Most candidates recognised that *P* was equal to the value of the gradient and *Q* was equal to the value of the intercept calculated in **(e)(iii)** for the first mark. Others tried to calculate *P* and *Q* by first substituting values into the given equation and then solving simultaneous equations. No credit is given for this as the question specifically asks for the answers in **(e)(iii)** to be used to determine *P* and *Q*. Strong candidates obtained values of *P* and *Q* with appropriate units. Others needed to include units with the answer. These can be deduced from the units used in the graph scales or from the equation given in **(f)**.

Question 2

In this question, candidates were required to investigate how the stopping distance of a model vehicle depends on its mass.

Successful collection of data

(a) (ii) Most candidates recorded a value of *L* to the nearest mm in the range 5.0 – 15.0 cm. A few candidates incorrectly gave a raw value to the nearest cm when the ruler can be read to the nearest mm.

(b) (ii) Some candidates recorded a value of *s* with a unit and stated repeated values. The value of *s* varies every time the trolley is released and so this measurement should be repeated. Many candidates did not repeat their readings.

(c) Most candidates recorded a value of *t* greater than 1 s to a precision of either 0.1 or 0.01 s. Some candidates omitted the units.

(e) (iii) Many candidates recorded new values for *t* and *s* for the trolley with a 100 g mass attached.

Quality

(d) Most candidates found that the longer the distance *s* the greater the time taken.

Presentation of data and observations

Display of calculation and reasoning

(b) (iv) Most candidates were able to calculate *x* from *s*–*L*.

(d) (i) Many candidates were able to calculate *v*. A few candidates forgot to use consistent units using $m\,s^{-1}$ when the units used for *x* were cm.

(d) (ii) Many candidates were able to relate the number of significant figures in *v* to *x* and *t*, gaining credit. Other candidates related to just one quantity, to the 'raw data' without specifying the quantities used, to the 'distance' without specifying which distance, or to the 'quantity with the least number of

significant figures' without stating the actual quantity involved. To gain credit, candidates should be encouraged to relate their answer to the specific experiment, rather than giving a general answer.

Analysis, conclusions and evaluation

(e) (iii) Few candidates compared the percentage difference in their values of v by testing it against a specified percentage uncertainty, either taken from **(b)(iii)** or estimated themselves. Candidates should state what they think is a sensible limit for the percentage uncertainty for this particular experiment. Answers such as "the difference in the two v values is very large/quite small" do not gain credit. Some candidates used a $v = kM$ approach to find k which was not appropriate in this question.

Estimating uncertainties in *s*

(b) (iii) Most candidates were familiar with the equation for calculating percentage uncertainty, though very few made a realistic estimate of the absolute uncertainty (2 – 10 cm). Most candidates stated the uncertainty as 1 mm, the smallest division on the ruler. Candidates should remember that the absolute uncertainty in the value of s depends not only on the precision of the measuring instrument being used but also on the nature of the experiment itself. In this particular experiment the value of s varies every time the trolley is released. Where measurements have been repeated, an acceptable method to estimate the absolute uncertainty is to calculate half the range of the results obtained earlier and use this as the absolute uncertainty.

Evaluation

(g) Many candidates found this section difficult. The key to this section is for candidates to identify genuine problems associated with setting up this experiment and in obtaining readings. An answer such as "it is difficult to measure time" is insufficient to gain credit without an explanation.

Candidates are encouraged to suggest detailed practical solutions that either improve technique or give more reliable data. They can improve their answers by stating the difficulties encountered during the experiment, e.g. the trolley did not travel in a straight line. They can also improve their answers by stating the methods used for each solution, e.g. use rulers to guide the trolley down the track. In doing this, candidates should look at how each solution helps this particular experiment.

Weaker candidates referred to using a camera without being specific as to what this will be used for. A video with a timer in the picture could be used so that the time for the end point can be determined more accurately. Credit is not given for suggestions that should be carried out anyway, such as repeating measurements and calculating averages or avoiding parallax errors (if this can easily be done). Some candidates explained that they started their timing on releasing the vehicle at the top of the board instead of at B which may explain some of the unusual trends in the candidates' data. Other candidates decided to use friction-free surfaces and travelling microscopes which would not help this particular experiment. Vague answers such as "turn fans off" or "use an assistant" are not usually valid.

A table giving details of limitations and potential improvements can be found in the mark scheme, together with some answers that did not receive credit.

PHYSICS

Paper 9702/34

Advanced Practical Skills 2

Key messages

- The Supervisor's Report and the sample set of results provided by each Centre form an important part of the marking process, and candidates may be disadvantaged if either is missing. The Supervisor's Report should include details of any difficulties or apparatus changes during the examination so that allowance can be made when marking. If help is provided to candidates, the Supervisor's Report **MUST** include candidate numbers and details of the assistance given.

- Candidates should aim to make graphical work as clear as possible, with scales chosen to make finding points and interpreting gradient read-offs easy. Candidates should be discouraged from making the points fill the whole grid by using awkward scales, e.g. 0.57 : 1. All that is required is that the points occupy at least half of each axis, and a sensible scale, e.g. 10 : 1 or 4 : 1 or 0.5 : 1, can always be found to achieve this.

- Common causes of lost credit in graph work are plotting 'blobs' (points with diameter greater than half a small square) and drawing thick or kinked lines of best fit. Using a sharp pencil and a transparent 30 cm ruler makes it much easier to plot points accurately and draw a good line of best fit.

- Candidates should always think about the precision of their recorded measurements. These should be to the smallest division of the measuring equipment used (e.g. 0.1 cm for a ruler, 0.01 mm for a micrometer, etc.) and no more. This precision should be shown even when the experimenter can select his/her own values (so lengths of wire of exactly 20 cm and 30 cm should be recorded as 20.0 cm and 30.0 cm when measured with a ruler).

- When deciding on the number of significant figures to use for a calculated quantity, candidates should remember that "the same as the least s.f. in the measurements used" does not apply if a subtraction is involved. For example 1/(22.1 cm – 21.8 cm) gives 3 cm^{-1} because the difference of the measurements (0.3 cm) only has 1 s.f.

General comments

Centres reported few problems with providing the necessary apparatus for the two questions.

Candidates had time to complete both questions and in most cases the instructions were understood and followed carefully. There was variation between Centres, producing a wide range of marks. Once again many Centres had prepared candidates well for the presentation of data in tables and graphs. This led to good marks in **Question 1** where even the weaker candidates were able to gain half of the available marks. In **Question 2** a number of candidates had difficulty interpreting the stopwatch display, and others found the discussion section challenging.

Comments on specific questions

Question 1

In this question, candidates were required to investigate the behaviour of an electrical circuit.

Successful collection of data

(a)(iii) Most answers included current values above 100 mA. Some either omitted the unit or gave the wrong unit (e.g. 120 A).

(b) Most candidates positioned the movable contact as instructed, leading to a value for l close to 50.0 cm, usually with the appropriate unit.

(c) Nearly all candidates recorded results for six (or more) different values of l, in most cases with a trend showing I increasing with increasing l. In the cases where results showed the wrong trend it is likely that the circuit was incorrect, or l had been measured from point B rather than point A.

Range and distribution of values

(c) Good answers used a suitably large part of this range by including values of l close to the maximum and the minimum available.

Table

(c) Tables were generally neat and clear. In good answers the headings included units separated from their quantity by using a "/" or by using brackets.

Several candidates recorded their values of l only to the nearest cm instead of the nearest mm (see Key Messages).

Calculations were done well although in many cases too few significant figures were given – candidates should remember that leading zeros (after the decimal point) do not count towards significant figures (e.g. 0.0079 mA^{-1} has only 2 s.f.).

Graph

(d)(i) There were many good graphs with simple scales and clear points.

A few graphs filled the entire grid, but only by using very awkward scales (it is only necessary to use at least half the grid in each direction). In a small number of cases the scale finished at 8000 cm^2 and the maximum value of l^2 was 8100 cm^2, so that the last point was either mis-plotted or omitted altogether.

The quality of many candidates' results (as indicated by scatter on the graph) was good, though for some the scatter was large or the trend was positive.

(d)(ii) Drawn lines were usually clearly defined although a few candidates had drawn their lines in two parts which did not join smoothly. Some candidates indicated that they were ignoring an outlying point by circling it, although some circled more than one point (this is not good practice when there are only six points).

Interpretation of graph

(d)(iii) In good answers a large triangle was added to the graph to indicate the coordinates used to calculate the gradient. The *y*-intercept could easily be read directly from the graph if the *x*-axis started at zero, but even so most candidates chose to calculate it, usually successfully. Most Centres had prepared candidates well in the clear presentation of their working, although a few candidates forgot to include a negative sign with their gradient value.

Drawing conclusions

(e) The majority of candidates identified the values of the constants *a* and *b* as their gradient and intercept values.

The unit for *a* proved more difficult, and errors were common with the power of ten (the problem often occurring during conversion between unit multiples).

Question 2

In this question, candidates were required to time a ball rolling a fixed distance down a ramp.

Successful collection of data

(a) Most candidates carried out this measurement successfully, though some may have used the wrong scale on a dual-scale rule and others omitted the unit.

(c) (i) In good answers candidates measured and recorded the two heights to the nearest mm. In a few cases the difference between the two heights was large (greater than 10 cm), suggesting that the instruction to raise one end of the track until the ball just started to roll had not been followed carefully.

(e),**(g)** Most candidates found sensible values for the rolling times and recorded repeated readings with an average. As in previous years, some candidates lacked experience of interpreting the display of a digital stopwatch and recorded times as low as 0.001 s.

Nearly all candidates found that the time was shorter for a steeper track.

Estimating uncertainties

(f) Some Centres had trained candidates to use realistic estimates of uncertainty based on reaction time, or half the range of repeated measurements. Many candidates used absolute uncertainties which were unrealistically small because they were based on the precision of the stopwatch (0.01 s).

Display of calculation and reasoning

(c) (ii) In nearly every case the candidate correctly calculated the value for $\sin\theta$, but many went further to calculate θ and recorded this angle on the $\sin\theta$ answer line.

(d) Many candidates understood that the significant figures given for $\sin\theta$ depended on the quantities used in the calculation, but nearly all listed h_1 and h_2 individually rather than Δh (see Key Messages).

(h) (i) Most candidates successfully calculated two values for the constant k, but there were some rounding errors and in a few cases the sine operation was repeated (i.e. $\sin(\sin\theta)$ was used).

Conclusions

(h) (ii) Candidates from some Centres produced good, clearly reasoned conclusions from their results, although many calculated the percentage difference between their k values but forgot to state what criterion they compared this difference to. Weaker candidates just argued that their k values were 'nearly equal'.

Evaluation

(i) In the limitations section most candidates achieved some credit, and there were some excellent answers receiving full credit. Many recognised that there were parallax difficulties when measuring h, and that it was difficult to stop the stopwatch at the right moment because of the ball's rapid movement. As in previous years, weak answers usually lacked sufficient detail, e.g. "timing was difficult" or "the ball moved fast".

In the improvements section many candidates identified the potential benefit of taking more values of θ, or using a video recorder with a timer included in the picture. In some cases the suggestions were vague, e.g. "use lightgates", or were not relevant, e.g. "turn off the fans".

The published mark scheme gives further detail of acceptable responses.

PHYSICS

Paper 9702/35
Advanced Practical Skills 1

Key messages

- The Supervisor's Report and the sample set of results provided by each Centre form an important part of the marking process, and candidates may be disadvantaged if either is missing. The Supervisor's Report should include details of any difficulties or apparatus changes during the examination so that allowance can be made when marking. If help is provided to candidates, the Supervisor's Report **MUST** include candidate numbers and details of the assistance given.

- Candidates should aim to make graphical work as clear as possible, with scales chosen to make finding points and interpreting gradient read-offs easy. Candidates should be discouraged from making the points fill the whole grid by using awkward scales, e.g. 0.57 : 1. All that is required is that the points occupy at least half of each axis, and a sensible scale, e.g. 10 : 1 or 4 : 1 or 0.5 : 1, can always be found to achieve this.

- Common causes of lost credit in graph work are plotting 'blobs' (points with diameter greater than half a small square) and drawing thick or kinked lines of best fit. Using a sharp pencil and a transparent 30 cm ruler makes it much easier to plot points accurately and draw a good line of best fit.

- Candidates should always think about the precision of their recorded measurements. These should be to the smallest division of the measuring equipment used (e.g. 0.1 cm for a ruler, 0.01 mm for a micrometer, etc.) and no more. This precision should be shown even when the experimenter can select his/her own values (so lengths of wire of exactly 20 cm and 30 cm should be recorded as 20.0 cm and 30.0 cm when measured with a ruler).

General comments

The general standard of the work done by the candidates was good and similar to last year, with a wide range of marks.

The majority of Centres had no problem in providing the equipment required for use by candidates. Any deviation between the requested equipment and that provided to the candidates should be written down in the Supervisor's Report, and this report must be sent with the scripts to Cambridge so that the Examiners can take this into consideration during the marking period. Experiments are designed with the view that Centres will have the apparatus as outlined in the syllabus available for use. Any help given to the candidate should be noted on the Supervisor's Report. Supervisors are reminded that under **no circumstances** should help be given with the recording of results, graphical work or analysis.

Candidates did not seem to be short of time and both questions were attempted by almost all candidates. They demonstrated good skills in the generation and handling of data but can improve by giving more thought to the critical evaluation of experiments.

There were no common misinterpretations of the rubric.

Comments on specific questions

Question 1

In this question, candidates were asked to measure the currents at two different points in the same circuit and to investigate how the currents depend on the total resistance of the circuit.

Successful collection of data

(a) (iv) Most candidates recorded correctly a value of I_1 that was less than 200 mA. A few candidates needed to include units in their answer. Others needed to recognise that the digital meter measured the current in mA rather than A.

(a) (v) Most candidates recorded a value for I_2 correctly, with a unit for current, and most obtained a value for I_2 which was greater than I_1. A few candidates omitted units for I_2.

(b) Almost all the candidates were able to set up the experiment without assistance, and collect six sets of values of *x*, I_1 and I_2 showing the correct trend (I_1 and I_2 increasing as *x* increases). A few candidates confused their values of I_1 and I_2.

Range and distribution of marks

(b) Most candidates recorded a suitable range of values for *x*. A few candidates could have made better use of the available range of values, needing a difference of at least 50 cm between the maximum and minimum values in order to gain credit.

Presentation of data and observations

Table

(b) Most candidates were awarded the mark for using the correct column headings in their tables. A few candidates needed to include units of m^{-1} for the 1/*x* column instead of m; others needed to recognise that the quantity I_1/I_2 is dimensionless with no units. The majority of candidates gave the raw values of *x* to the nearest mm; others needed to take account of the precision of the metre rule, recording answers to the nearest mm rather than the nearest cm or 10 cm. Most expressed the values of I_1/I_2 to the same number of significant figures as, or one more than, the least number of significant figures in the raw values of I_1 and I_2. The great majority of candidates calculated the values of I_1/I_2 correctly.

Graph

(c) (i) Candidates were required to plot a graph of I_1/I_2 against *x*. Most candidates gained credit for drawing appropriate axes, with labels and sensible scales, though some chose difficult or awkward scales; others plotted fractions on the 1/*x* axis, producing a non-linear scale. (These candidates often lost marks for incorrect plotting of points or incorrect read-offs when calculating the gradient or intercept.) Many candidates gained credit for plotting their tabulated readings correctly; others needed to draw plotted points so that the diameter is equal to, or less than, half a small square. Some candidates can improve by plotting the points more accurately i.e. to within half a small square.

Analysis, conclusions and evaluation

Interpretation of graph

(c) (iii) Many candidates used a suitably large triangle to calculate the gradient, gaining credit for the read-offs and substitution into $\Delta y/\Delta x$ to find the gradient. Other candidates needed to check that the read-offs used were within half a small square of the best fit line drawn, show the substitution clearly into $\Delta y/\Delta x$ (not $\Delta x/\Delta y$), or check that the triangle for calculating the gradient was large enough (the hypotenuse should be at least half the length of the line drawn) in order to gain credit. Some candidates correctly read off the *y*-intercept at $x = 0$ directly from the graph. Others needed to check that the *x*-axis started with $x = 0$ (i.e. no false origin) for this method of finding the intercept to be valid. Several candidates correctly substituted a read-off into $y=mx+c$ to determine the y-intercept. Others needed to check the point chosen was actually on the line of best fit and not just in the table.

Drawing conclusions

(d) Most candidates recognised that *P* was equal to the value of the gradient and *Q* was equal to the value of the intercept calculated in **(c)(iii)** for the first mark. Others tried to calculate *P* and *Q* by first substituting values into the given equation and then solving simultaneous equations. No credit is given for this as the question specifically asks for the answers in **(c)(iii)** to be used to determine *P* and *Q*. Most candidates obtained values of *P* and *Q* with appropriate units. Others needed to include units with the answer which can be deduced from the units used in the graph scales or from the equation given in **(d)**.

Question 2

In this question, candidates were required to investigate how the motion of a spring depends on its length.

Successful collection of data

(a) (i) Most candidates recorded a value for *D* to the nearest mm, with a consistent unit. Others needed to take account of the precision of the rule used to measure *D* by recording their value to the nearest mm rather than 0.1 mm.

(b) (ii) Most candidates recorded a value for *x* to the nearest mm, with an appropriate unit, though a few candidates recorded their value to too great a degree of precision, or omitted units.

(c) (iv) Many candidates recorded a value for *T* successfully, though some measured the time for 10*T* but neglected to divide by 10, so recorded a value which was outside the permitted range. Most candidates repeated their measurements, either by recording the value of 10*T* at least once, or by measuring *T* several times and then calculating the average value.

(d) (iv) Almost all candidates recorded a second value for *x*.

(e) All candidates recorded a second value for *T*.

Quality

(e) Almost all candidates found that the first value of *T* (for the longer spring) was greater than the second value and were awarded this mark.

Display of calculation and reasoning

(b) (iii) Almost all candidates were able to calculate *V* correctly, though some omitted units.

(f) (i) The great majority of candidates were able to calculate *k* for the two sets of data, showing their working and so gaining credit.

(f) (ii) Very few candidates were able to justify the significant figures they had given for the values of *k* correctly. They should try to link the significant figures of *k* to the significant figures of the raw data used to calculate *k*. The raw data should be stated explicitly – in this case *D*, *x* and *T*.

Analysis, conclusions and evaluation

(f) (iii) Most candidates calculated the percentage difference between their values of *k*, and then tested it against a specified percentage uncertainty, either taken from **(a)(ii)** or estimated themselves. Answers such as “the difference in the two k values is very large/quite small” do not gain credit.

Estimating uncertainties in *D*

(a) (ii) Most candidates were familiar with the equation for calculating percentage uncertainty, and made realistic estimates of the absolute uncertainty – typically 1 mm. Where measurements have been repeated, an acceptable method to estimate the absolute uncertainty is to calculate half the range of the results obtained earlier and use this as the absolute uncertainty. A few candidates needed to ensure that the value for *D* and the estimate of the absolute uncertainty are recorded in the same units when completing the calculation.

Evaluation

(g) Many candidates recognised that two sets of data were insufficient to draw a valid conclusion and suggested repeating the experiment for other values of *x* and then plotting a suitable graph. Some identified the potential parallax error in measuring *D* and suggested improvements such as using Vernier calipers or a micrometer. Others acknowledged the difficulty in identifying the start or end of an oscillation, judging exactly when an oscillation was complete, and some observed that the mass tends to swing from side-to-side like a pendulum rather than just oscillating vertically.

The key to this section is for candidates to identify genuine problems associated with setting up this experiment and in obtaining readings. Many candidates could improve by giving more detail in their answers e.g. "parallax error measuring *D*" rather than just "parallax error". Answers such as "it is difficult to measure *T*" are just re-stating the problem set, so are not credited. A careful description of why it is difficult to measure *T* is required e.g. "the times are small so there is a large percentage uncertainty in *T*", or "it is difficult to judge exactly when an oscillation is complete".

Candidates are encouraged to suggest detailed practical solutions that either improve technique or give more reliable data. They can improve their answers by stating the methods used for each solution e.g. "video the experiment and then playback using the clock on the video to measure *T*" ("use a video and playback" alone is insufficient). Credit is not given for suggestions that could be carried out in the original experiment, such as repeating measurements or avoiding parallax errors by looking at an instrument at eye level. Vague answers such as "systematic error", "bench not horizontal", "turn fans off" or "use an assistant" are not usually valid.

A table giving details of limitations and potential improvements can be found in the published mark scheme, together with some answers that did not receive credit.

PHYSICS

Paper 9702/41
A2 Structured Questions

Key Messages

- Many candidates were better at performing mathematical calculations than constructing answers using sentences of continuous prose. It is important for candidates to practise answering questions that require them to write complete sentences.
- It is to be expected that, for candidates approaching the end of their course, the use of physics terms should be precise. For example 'rate of emission' should not be simplified to 'fast' or 'slow'. Similarly, power, energy and work done should be used in the correct context. Candidates should be encouraged to use correct terminology.
- Candidates should read the question carefully before they construct an answer. Those who merely scan the question sometimes overlook key details which inevitably result in a weak answer. They should also focus on any command words such as 'state' or 'explain' to ensure that they give a relevant response. The Appendix of the syllabus gives a glossary of terms that are used.

General Comments

There was no real evidence amongst adequately prepared candidates of a shortage of time.

Some candidates do seem to waste valuable time by writing out large portions of the question. Paraphrasing a question does not assist with any necessary explanation, and it can be a disadvantage.

Comments on Specific Questions

Section A

Question 1

(a) The requirement that the masses are point masses or that the dimensions of the masses are much smaller than their separation was omitted in the majority of answers.

(b) (i) Candidates were expected to 'show' and, consequently, explanation is essential. In many instances, expressions for gravitational force and centripetal force were merely equated. The expressions were not identified and it was not stated that the gravitational force *provides* the centripetal force.

(ii)1. The relevant expression for this calculation was given in the question. Despite this, errors were very common, many being caused by the rounding of answers at inappropriate points in the calculations. Candidates do need to realise that $(1/R - 1/r)$ is not equal to $1/(R - r)$.

(ii)2. Again, there were many errors associated with the manipulation of numerical values. A common error was to use the value of G from the Data page rather than the quoted value of GM for this planet.

(ii) Candidates rarely made reference to the answers in **(i)** but rather, they just stated that the speed had increased, without reference to any change in the kinetic energy.

Question 2

In questions such as this, candidates should emphasise the relevance of atoms/molecules, rather than refer to just 'energy' or 'energy of the system'.

(a) (i) The random nature of the motion of atoms/molecules was frequently omitted. Internal energy is not associated with the ordered kinetic energy of the motion of the whole system.

(ii) The absence of intermolecular/interatomic forces was appreciated by most. A common error was to refer to kinetic energy without any reference to atoms/molecules.

(b) There were very few correct answers. In most scripts, no distinction was made between kelvin and Celsius temperatures. With few exceptions, it was stated, quite wrongly, that because the temperature had doubled, the energy would double.

Question 3

(a) Frequently, reference was made either to the temperatures being the same or to zero net transfer of heat between the spheres, but not both. Common errors were to refer to the two spheres having constant temperatures or the same thermal energy.

(b) (i) Most answers were correct. The most common error was to give the reciprocal of the correct result.

(ii) This part of the question proved to be difficult. There were few answers where it was stated that thermal energy would be lost to the surroundings, giving rise to an overestimate. Many answers referred to thermal energy lost to the tube, to the heater or even to the water itself.

Question 4

(a) There were some good answers where the features of the graph were linked correctly to the aspects of simple harmonic motion. Others either merely identified features of the graph without discussing their relevance or gave a definition of simple harmonic motion.

(b) (i) Most answers were correct.

(ii) In the great majority of scripts, the general procedure for the calculation of the frequency was understood. However, power-of-ten errors were common.

(c) There were very few candidates who had any real appreciation of the situation. In nearly all answers, it was thought that the weight of the ball would either prevent simple harmonic oscillations or cause heavy damping. Any effect on the extension of the springs was not considered.

Question 5

(a) (i) Definitions were usually satisfactory. The use of the term *potential difference* when referring to a single conductor was suspect.

(ii) The fact that the charges on the two plates are equal in magnitude but of opposite sign was not included in many answers. Many thought that the insulator had some effect on the 'cancellation' of the charge. There were few answers that considered the energy stored as a result of work done to separate the charges on the plates.

(b) (i) Most answers were correct.

(ii) It was uncommon to find an adequate explanation as to the distribution of charge on the plates of the capacitors. Furthermore, in many scripts, the powers-of-ten were ignored when arriving at the answer of 72 μC.

(iii)1. Despite being given the charge on the capacitor of known capacitance, a significant number of candidates could not calculate the potential difference.

(iii)2. Of those candidates who did obtain the correct answer for the p.d. across X, many did not appreciate how to determine the p.d. across the parallel combination.

Question 6

(a) (i) Many candidates thought that the particle must be moving at right-angles to the direction of the field. A common answer was to state that the particle must be normal to the field, without any reference to motion.

(ii) The most usual answer was $F = Bqv$, with no reference to an angle.

(b) (i) There appeared to be a large element of guesswork when attempting to identify the correct face.

(ii) Surprisingly, many candidates who did identify the correct face in **(i)**, did not then specify this in **(ii)**. Frequently, the faces specified where not on opposite faces of the block.

(c) Some candidates did recognise that an electric field would be established and that this field would give rise to a force on the electrons.

Question 7

(a) In many answers, it was not made clear that the induced e.m.f. gives rise to effects that tend to oppose the change giving rise to the e.m.f. Often, the e.m.f. was stated to 'oppose the change in flux linkage'.

(b) (i)1. The most common acceptable answer was 'easy to magnetise and demagnetise'. Some did, quite correctly, refer to improved flux linkage. A common incorrect response referred to iron being a good electrical conductor.

(i)2. Most answers did make reference to eddy currents and/or energy losses. However, a common error was to believe that the currents and energy losses are prevented, rather than reduced.

(ii) Many candidates were not able to give a satisfactory explanation of the operation of a transformer. The function of the core to link the flux from the primary to the secondary was frequently omitted. In many weaker accounts, it was thought that a current passes in the core from the primary coil to the secondary coil.

Question 8

(a) The expression relating photon energy to frequency was omitted in many scripts.

(b) The majority of answers lacked precision. References were made to 'energy' when what was required was maximum kinetic energy. Likewise, 'number of electrons emitted' was quoted when what should have been considered was rate of emission of electrons.

(c) There were some very good answers here, with a final statement justified by calculations. It was unfortunate that some candidates gave correct solutions in terms of either energy or frequency or wavelength but did not complete the answer by giving a reason for their conclusion.

Section B

Question 9

(a) In general, all three marks were scored.

(b) (i) The majority of answers were based, incorrectly, on some form of sinusoidal wave. This was despite being informed that the circuit is for a comparator. Of those who did draw a square wave, many indicated either incorrect cross-over points or incorrect polarity of the output.

(ii) A significant minority of candidates were unaware of the symbol for an LED. In most cases where symbols were drawn, these were shown as being connected between the output and earth.

Question 10

Descriptions of MRI and the use of ultrasound were few in number.

There were some good comprehensive descriptions but, on the other hand, many accounts were confused and did little more than state that a computer is used to form a 3D image that can be rotated.

More able candidates frequently omitted to state that X-ray images from different angles are combined to form an image of a single slice and that this process is repeated for many slices to create the 3D image.

Candidates frequently jumped from X-ray images at different angles to using a computer to form a 3D image.

Question 11

(a) Often statements were made that were not relevant to the question. Candidates had memorised facts related to other aspects of communication and these were written down regardless.

There is a common belief that noise does not affect digital signals. Candidates should realise that noise is added to digital signals, but it may be eliminated by means of regenerator amplifiers.

(b) (i) In **part 1**, candidates were expected to state that higher frequencies could be reproduced. In **part 2**, smaller changes in amplitude would be detected. Most candidates merely stated that the quality would be either better or worse. Frequently, a longer word length was associated with poorer quality.

(ii) In general, this calculation was completed successfully. Many of those who did not arrive at the correct response produced answers which, given a few moments of thought, would have been recognised as being of an unreasonable order of magnitude.

Question 12

(a) (i) Cross-linking was frequently confused with noise.

(ii) A common misunderstanding was to attribute shielding of the core to the insulator surrounding the core, without mentioning the outer braid. The fact that the outer braid is earthed was mentioned in a small minority of scripts.

(b) This type of calculation is becoming more familiar to candidates but they do need to apply caution. Amplification and attenuation are frequently confused.

A significant number of calculations started by assuming that the attenuation along the wire pair is 25 dB. The most usual correct method was to determine the minimum signal power at the receiver and then to calculate the attenuation in the wire pair.

PHYSICS

Paper 9702/42
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PHYSICS

Paper 9702/43
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General Comments

The paper gave rise to the award of marks over a wide range. There were some very high scoring scripts that demonstrated a good understanding across the full range of syllabus topics. Other candidates had significant gaps in their knowledge and understanding of the syllabus content.

Candidates should be encouraged to check that their numerical answers have a reasonable magnitude. If the value of a numerical answer is not sensible, candidates should then consider what mistake they may have made, such as a power-of-ten error.

Comments on Specific Questions

Section A

Question 1

(a) (i) The great majority of answers correctly identified N as meaning the number of molecules. It was inappropriate to refer to the number of atoms because the question states that m is the mass of a molecule.

(ii) Most answers were correct. A small minority wrongly stated root-mean-square speed.

(b) (i)1. There were many correct calculations. Almost all of the candidates remembered to convert the units of the temperature from degrees Celsius to kelvin. Weaker candidates sometimes made a power-of-ten error when converting the units of the volume.

(i)2. Two methods of calculation were evident. Candidates either multiplied the amount of gas, in mol, by the Avogadro constant or they used the equation $pV = NkT$.

(ii) Although there were some well constructed calculations, two common errors were evident. Either the amount of gas, in mol, was confused with the number of atoms of gas or the mass of 1 mol was confused with the mass of 1 atom. A few candidates also gave the mean-square speed as their final answer, rather than the root-mean-square speed.

Question 2

(a) (i)1. Only a minority of the candidates appreciated that the displacement of the trolley is zero when the velocity is maximum.

(i)2. A common mistake was to state two different times at which the acceleration is maximum in opposite directions, rather than in one direction. Some candidates could have avoided this error by reading the question more carefully.

(ii) With few exceptions, the correct frequency was determined.

(iii) The phase difference between the displacement and the velocity was poorly understood. Many candidates also forgot to include a correct unit with the answer.

(b) The vast majority of answers were correct.

(c) It was generally appreciated that the oscillations ought to be damped, but there were few answers that stated how this would be done. Correct answers usually involved attaching something to the trolley that would increase the drag force on it without significantly increasing its mass e.g. a sheet of cardboard. No credit was given for answers that suggested a significant change in the mass of the trolley or a change in the spring constant of the springs.

Question 3

(a) Many candidates did not read the question carefully and therefore stated what was meant by a gravitational field and an electric field, rather than a line of force in these two fields.

(b) The most commonly stated similarity was that both fields are radial. Many other similarities were stated with insufficient precision for the award of credit. Candidates were more successful in stating a difference between the fields. The most commonly stated difference was that gravitational force always acts towards the sphere whereas electric force can act towards or away from it, depending upon on the sign of the charge on the sphere.

(c) The motion of the proton between the plates is dictated by the relative sizes of the gravitational force and the electric force. It was expected that candidates would calculate the magnitudes of these two forces and show that the electric force is much greater than the gravitational force. A common error was to compare directly the magnitudes of the gravitational field strength and the electric field strength. Candidates sometimes provided only a qualitative explanation, even though the question asked for a quantitative one.

Question 4

(a) Candidates needed to explain that the force on the proton is normal to both the proton's velocity and to the direction of the magnetic field. This force provides the centripetal force needed for circular motion.

(b) The majority of candidates were able to equate the two appropriate expressions for the force on the proton. All steps in a derivation must be clearly shown and so it was necessary to explicitly name the centripetal force and the magnetic force when first introducing their corresponding expressions.

Question 5

(a) There were many satisfactory answers, although some candidates confused magnetic flux with magnetic flux linkage.

(b) For the award of credit, the entire graph line needed to be shown. This included the parts of the graph line that lie along the time axis where there is zero e.m.f.

(c)(i) Faraday's law of electromagnetic induction was usually quoted correctly.

(ii) Few candidates appreciated that a short 'pulse' of e.m.f. would be produced by the probe both on entering and leaving the magnetic field. Even fewer realised that the e.m.f. of these two pulses would be in opposite directions.

Question 6

(a) (i) The positive connection to the load resistor was usually identified correctly.

(ii) The majority of candidates realised that diodes B and D were conducting.

(b) (i) Two methods of calculation were used. The most common method was to calculate the r.m.s. voltage across the resistor and then use this to find the mean power dissipated. The other method was to use the peak voltage across the resistor to calculate the peak power dissipated, which was then halved to get the mean power. There were many calculations where there was confusion between the peak power and the mean power.

(ii) The capacitor was usually positioned correctly in the circuit, although sometimes it was wrongly placed in series with the resistor.

(c) The entire graph line needed to be shown. This included the parts of the graph line that lie along the time axis where there is zero potential difference. A small minority of candidates ignored the instruction to draw on Fig. 6.2 and instead drew their graph on a blank area of the page. This made it very difficult to show that the half-wave rectification occurs with the same period and the same peak value of potential difference as the full-wave rectification.

Question 7

(a) The de Broglie wavelength is the wavelength associated with a particle that is moving. In many scripts, the formula $\lambda = h/p$ was quoted and then the symbols h and p were explained. The question asked for a statement as to what is meant by the de Broglie wavelength and so consequently this approach was not given credit.

(b) (i) The calculation of the de Broglie wavelength involved several steps that presented few problems for the more able candidates. Weaker candidates were usually able to calculate the kinetic energy of the electron, but often made the mistake of substituting this value of energy into the formula $E = hf$.

(ii) Very few candidates appreciated that the electrons would be diffracted by the crystal because their de Broglie wavelength was similar in value to the separation of the atoms in the crystal. Many answers alluded, quite incorrectly, to the frequency associated with the electron being similar in value to the natural frequency of the crystal so that resonance would occur.

Question 8

(a) Full credit was usually awarded for this part of the question.

(b) (i) Many candidates were confused by the instruction to calculate the binding energy in u. Consequently, most of the candidates who did calculate the correct value of 1.808 u made needless attempts to convert their answer into units of J or MeV.

(ii) Candidates should be advised that when they are asked to 'show' that a given answer is correct, they must show explicitly every single step in their derivation of the final answer. Many calculations were poorly presented and omitted steps.

(c) The binding energies of the product nuclei needed to be calculated and then subtracted from the binding energy of the uranium nucleus. A common error was to calculate the binding energy of a nucleus by calculating the product of its binding energy per nucleon and its mass, in u, rather than its binding energy per nucleon and its nucleon number.

Section B

Question 9

(a) Almost without exception, the light-emitting diodes were correctly named.

(b) There were few accurate descriptions of the function of the processing unit. The operational amplifier gives a high or low (+5 V or –5 V) output that is dependent upon which of the inputs is at a higher potential. No credit was given for answers that simply stated that the operational amplifier amplifies the potential difference between its two inputs.

(c) (i) Many candidates alluded to a potential divider, but few appreciated that the function of the two resistors is to provide a constant reference potential at the non-inverting input of the operational amplifier.

(ii) It was seldom appreciated that the variable resistor is used to set the temperature at which the operational amplifier's output potential switches polarity.

(d) The great majority of answers correctly stated that the output device would be a relay. However, candidates were less successful when positioning the relay in the circuit diagram. Many drew an inappropriate resistor symbol to represent the coil of the relay. Others incorrectly reversed the positions of the coil and the switch. Similarly, the diode was often drawn either in the wrong position or with the incorrect polarity.

Question 10

Well prepared candidates, with the required knowledge of how pixel readings are developed in CT scanning, often received full credit for their answers. However, candidates possessing only a superficial knowledge scored comparatively few marks. Such candidates would benefit from practising answering this type of question when they are initially developing their understanding of CT scanning.

Question 11

(a) Most candidates realised that either the amplitude or the frequency of the carrier wave varies in synchrony with the displacement of the information signal. However, a common misconception was that the carrier wave varies in synchrony with the frequency or amplitude of the information signal. It was seldom mentioned that the carrier wave is a high frequency wave.

(b) The most commonly-stated correct reasons for using modulated carrier waves were that they have a longer transmission range and require a shorter aerial. Other correctly stated reasons were that modulated carrier waves suffer less distortion and allow more than one radio station to operate simultaneously in the same region.

Question 12

(a) For the award of credit, it was essential that candidates adequately described their suggested applications. For example, when one application of a coaxial cable is to link an aerial to a television, it is not sufficient to simply state 'television' as the answer.

(b) (i) The majority of calculations were correct, although one common error was to reverse the ratio of the input and output powers in the expression for the attenuation. Many of the candidates that made this error did not seem to notice that their calculated output power was much greater than the input power. Candidates should always be encouraged to consider the magnitude of their answer. If it is not sensible, they may then be able to quickly identify a mistake in their working.

(ii) Candidates had mixed success with this part of the question. The most frequent error was to use an incorrect value of input power in their calculation.

PHYSICS

Paper 9702/51
Planning, Analysis and Evaluation

Key Messages

- Candidates should be encouraged to read through the whole question paper before starting their answer.
- In **Question 1**, candidates must ensure that their answers are detailed and include explanations and answer the planning experiment set.
- Graphical work should be carefully attempted and checked. Candidates are advised to check points that do not lie on the line of best fit; care is needed when reading information from the graph.
- The numerical answers towards the end of **Question 2** require candidates to show all their working, particularly when determining both percentage and absolute uncertainties.
- The practical skills required for this paper should be developed and practised over a period of time with a 'hands-on' approach.

General Comments

Question 2 was generally answered better than **Question 1** and a large number of candidates scored very highly. It was evident that Centres had spent time on the analysis section enabling their candidates to score all of the fifteen marks available. For **Question 1**, candidates should include greater detail in their answers, and should be reminded that the boxes for the Examiner's use at the end of the question give a useful hint about the criteria used for awarding marks. In **Question 2** careless mistakes were often made in the plotting of points on the graph or not reading off information from the graph correctly. Furthermore **(c)(iv)** was poorly answered with many candidates not realising that there was a false origin and that the *y*-intercept should have been calculated by substituting a point from their line into the equation of a straight line. Candidates did not always indicate the methods used to determine either absolute or percentage uncertainties. Furthermore some candidates were sometimes confused between absolute and percentage uncertainties.

It is clear that the candidates scoring the highest marks have experienced a practical course where the skills required for this paper are developed and practised over a period of time with a 'hands-on' approach. To assist Centres, Cambridge have produced two booklets – Teaching AS Physics Practical Skills and Teaching A2 Physics Practical Skills which are available from the Teacher Support website.

Comments on Specific Questions

Question 1

Candidates were required to design a laboratory experiment to investigate how the maximum induced e.m.f. in a coil varies with the speed at which a bar magnet drops through a coil.

Candidates are advised to start **Question 1** by considering carefully the problem to be solved and in particular the variables that need to be kept constant for the experiment to be a fair test. The initial marks were awarded for correctly identifying the independent and dependent variables. Many candidates correctly realised that the speed of the bar magnet was the independent variable and the maximum induced e.m.f. was the dependent variable. Some candidates suggested varying the e.m.f. and then measuring the speed of the bar magnet. A further mark was available for stating that the number of turns on the coil should be kept constant. As has been indicated in previous reports the word "controlled" is not an acceptable alternative to the word "constant".

Five marks are available for the methods of data collection. Candidates were expected to draw a labelled diagram of the arrangement of their equipment suitable for this investigation. Diagrams must be clearly labelled. In this experiment, candidates were expected to clearly indicate a bar magnet falling vertically through a coil; some candidates drew horizontal coils. The second mark was awarded to candidates who used a voltmeter or cathode-ray oscilloscope to measure the induced e.m.f. An additional detail mark could have been scored for explaining how the oscilloscope or data logger could be used to determine the maximum e.m.f. Many candidates drew circuit diagrams incorrectly containing sources of e.m.f.—candidates should be advised to think carefully about the problem set. Other common errors included the use of variable resistors and ammeters incorrectly connected in their circuits. A mark was awarded for the method to change the speed of the bar magnet, e.g. change the height from which the bar magnet is dropped.

Two marks were awarded for the method to determine the speed at which the bar magnet falls. There were several methods possible. In each possible method candidates were expected to explicitly state the measuring instrument used. A common error was to state that light gates would measure the velocity. To gain both marks, candidates were expected to give detailed answers as to the exact distance that was measured and/or the exact time that was measured. To score the second mark, candidates needed to include an appropriate equation. When discussing the use of light gates or motion sensors, candidates must explain the measurements that are needed. For example, if light gates are connected, then there must be a distance measurement made for the data logger or computer to determine the velocity.

There are two marks available for the analysis of the data. It is expected that candidates would state the quantities that should be plotted on each axis of a graph for the first mark. The second mark was awarded for explaining that the relationship would be valid if a straight line passing through the origin was produced—this needed to be explicitly stated and credit was not given for a sketch graph. Candidates who were not awarded the second mark often did not realise that the relationship would only be valid if a straight line passing through the origin was produced. Some candidates did not state that the line had to be straight.

There was one mark available for the describing an appropriate safety precaution. Candidates should be encouraged to ensure that safety precautions are relevant to the experiment and are clearly reasoned; vague answers did not gain credit. Creditworthy responses included the use of a sand bucket or cushion to catch the magnet.

There are four marks available for additional detail. Candidates should be encouraged to write their plans including appropriate detail; often candidates' answers suggested they lacked sufficient practical experience. Vague responses did not score. In addition to the points already mentioned above, credit was also given for:

- use of a coil with a large number of turns, strong magnet or large heights so as to produce a measurable induced e.m.f.;
- use of the same magnet or magnet of the same strength;
- use of a short magnet or short coil so that the velocity is almost constant;
- use of a vertical tube;
- a method to support the coil or tube;
- taking many readings of the e.m.f. for each velocity and then obtaining an average value.

It must be emphasised that those candidates who have followed a 'hands on' practical course during their studies are much better placed to score these additional detail marks. It is essential that candidates' answers give detail relevant to the experiment in question rather than general 'textbook' rules for working in a laboratory.

Question 2

In this data analysis question, candidates were given data on how the minimum potential difference required to cause an LED to emit its characteristic wavelength varied with the wavelength.

(a) This was generally well answered. Candidates had to indicate that the *y*-intercept was negative and some omitted *e*.

(b) Most candidates correctly included the column heading, although some candidates did not include a distinguishing mark between the quantity and unit. The calculated and recorded values of $1/\lambda$ needed to be given to an appropriate number of significant figures. A number of candidates lost credit for rounding errors. It is expected that the number of significant figures in calculated

quantities should be the same, or one more than, the number of significant figures in the raw data. The absolute uncertainties in $1/\lambda$ were usually calculated correctly. The Examiners allow a number of different methods to determine the absolute uncertainties and do not penalise significant figures at this stage.

(c) (i) The graph plotting was quite variable. Common mistakes included not plotting the points correctly—candidates should check suspect plots. Candidates should also be advised to ensure that the size of the plotted points is small; large 'blobs' were not credited. Candidates should be encouraged to check points that do not appear to follow the line of best fit. A number of candidates did not construct the error bars accurately.

(ii) Most candidates attempted to draw the line of best fit. Candidates should be encouraged to ensure that there is a balance of points on each side of the line. The worst acceptable straight line should be either the steepest possible line or the shallowest possible line that passes through the error bars of all the data points used for the line of best fit. The majority of the candidates clearly labelled the lines on their graph; lines not indicated may be penalised. A number of candidates did not score marks for their lines since they were not straight.

(iii) This part was generally answered well, although candidates could often make their working clearer. Some candidates did not use a sensibly-sized triangle for their gradient calculation. A large number of good candidates clearly indicated the points that they used from the line of best fit. Some candidates used the points from the table but did not gain credit because they did not lie on the line of best fit. A common error was to misread the scales, e.g. using 2.8 instead of 2.08. A large number of candidates did not realise that the *x*-axis had a power of ten i.e. $(1/\lambda)/10^6$ m^{-1}. To determine the absolute uncertainty in the gradient, candidates were expected to find the difference between the gradient of the line of best fit and the gradient of the worst acceptable line. Again stronger candidates clearly indicated the points that they have used from the worst acceptable line.

(iv) Many candidates did not realise that there was a false origin. Stronger candidates substituted a value from their line into $y = mx + c$. To determine the absolute uncertainty in the *y*-intercept, candidates need to determine the *y*-intercept from the worst acceptable line – again a point from the worst acceptable line and the gradient of the worst acceptable line needed to be substituted into $y = mx + c$.

(d) (i) Most errors here were caused by incorrect reading of values from the *x*-axis which resulted in candidates gaining an answer of the order of 10^{28}.

(ii) Stronger candidates found the percentage uncertainty in the gradient. For the award of this mark, working needed to be shown.

(e) Candidates needed to determine a value for *B* with an appropriate unit. A large number of candidates stated that the unit was J or C V, while many others omitted the unit. Some candidates suggested incorrectly eV. A significant small number suggested tesla—candidates should be encouraged to read carefully the question set. There were many methods allowed to determine the absolute uncertainty in this value of *B*; candidates must show clearly their working. A number of methods are to be found in the Mark Scheme. Some weaker candidates wrote down the answer from **(c)(iv)**.

It is essential that candidates clearly show their working, particularly to questions such as **(d)(ii)** and **(e)**. Candidates should also be clear as to their understanding of percentage uncertainty and absolute uncertainty.

PHYSICS

Paper 9702/52
Planning, Analysis and Evaluation

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General Comments

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There are four marks available for additional detail. Candidates should be encouraged to write their plans including appropriate detail; often candidates' answers suggested they lacked sufficient practical experience. Vague responses did not score. In addition to the points already mentioned above, credit was also given for:

- use of a coil with a large number of turns, strong magnet or large heights so as to produce a measurable induced e.m.f.;
- use of the same magnet or magnet of the same strength;
- use of a short magnet or short coil so that the velocity is almost constant;
- use of a vertical tube;
- a method to support the coil or tube;
- taking many readings of the e.m.f. for each velocity and then obtaining an average value.

It must be emphasised that those candidates who have followed a 'hands on' practical course during their studies are much better placed to score these additional detail marks. It is essential that candidates' answers give detail relevant to the experiment in question rather than general 'textbook' rules for working in a laboratory.

Question 2

In this data analysis question, candidates were given data on how the minimum potential difference required to cause an LED to emit its characteristic wavelength varied with the wavelength.

(a) This was generally well answered. Candidates had to indicate that the *y*-intercept was negative and some omitted *e*.

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(iii) This part was generally answered well, although candidates could often make their working clearer. Some candidates did not use a sensibly-sized triangle for their gradient calculation. A large number of good candidates clearly indicated the points that they used from the line of best fit. Some candidates used the points from the table but did not gain credit because they did not lie on the line of best fit. A common error was to misread the scales, e.g. using 2.8 instead of 2.08. A large number of candidates did not realise that the *x*-axis had a power of ten i.e. $(1/\lambda)/10^6$ m^{-1}. To determine the absolute uncertainty in the gradient, candidates were expected to find the difference between the gradient of the line of best fit and the gradient of the worst acceptable line. Again stronger candidates clearly indicated the points that they have used from the worst acceptable line.

(iv) Many candidates did not realise that there was a false origin. Stronger candidates substituted a value from their line into $y = mx + c$. To determine the absolute uncertainty in the *y*-intercept, candidates need to determine the *y*-intercept from the worst acceptable line – again a point from the worst acceptable line and the gradient of the worst acceptable line needed to be substituted into $y = mx + c$.

(d) (i) Most errors here were caused by incorrect reading of values from the *x*-axis which resulted in candidates gaining an answer of the order of 10^{28}.

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It is essential that candidates clearly show their working, particularly to questions such as **(d)(ii)** and **(e)**. Candidates should also be clear as to their understanding of percentage uncertainty and absolute uncertainty.

PHYSICS

Paper 9702/53
Planning, Analysis and Evaluation

Key Messages

- Candidates should be encouraged to read through the whole question paper before starting their answer.
- In **Question 1**, candidates must ensure that their answers are detailed and include explanations and answer the planning experiment set.
- Graphical work should be carefully attempted and checked. Candidates are advised to check points that do not lie on the line of best fit; care is needed when reading information from the graph.
- The numerical answers towards the end of **Question 2** require candidates to show all their working, particularly when determining both percentage and absolute uncertainties.
- The practical skills required for this paper should be developed and practised over a period of time with a 'hands-on' approach.

General Comments

Question 2 was generally answered better than **Question 1**, and a large number of candidates scored very highly. It was evident that Centres had spent time on the analysis section enabling their candidates to score all of the fifteen marks available. In **Question 1**, many candidates had difficulty fully understanding the task set. Candidates also need to include greater detail in their answers. There are a number of boxes at the end of the question that are for the Examiner's use; they also give a useful hint to candidates about the criteria used for awarding marks.

Graphical work for **Question 2** is very varied; some is outstanding, whilst some is careless. Mistakes were often made in the plotting of points on the graph—candidates need a ruler that is long enough to draw the lines at one attempt rather than moving a short ruler along, as this often creates a bend in the line. Candidates should also be advised to draw error bars in full, rather just a dash at the top and bottom, since this method leads to difficulties in estimating the worst acceptable straight line. Candidates did not always indicate clearly the method used to determine either absolute or percentage uncertainties.

As has been mentioned in previous reports, this paper is designed to test candidates' practical experience; this is best achieved through the teaching of a practical course where the skills required for this paper are developed and practised over a period of time with a 'hands-on' approach. To assist Centres, Cambridge have produced two booklets – Teaching AS Physics Practical Skills and Teaching A2 Physics Practical Skills that are available from the Teacher Support website.

Comments on Specific Questions

Question 1

Candidates were required to design a laboratory experiment using two identical light sources to test a relationship between the angle when these two sources appear as one and the wavelength of the light from the sources.

Candidates are advised to start **Question 1** by considering carefully the problem to be solved and, in particular, the variables that need to be kept constant for the experiment to be a fair test. The initial two marks were awarded for correctly identifying the independent and dependent variables. These were

frequently confused; many weaker candidates suggested changing the angle and then determining the wavelength. A further mark was available for stating that the two sources should be of similar intensity or brightness. Candidates should be encouraged to think about the problem set so that the quantities that need to be kept constant are relevant to the experiment being planned. Some candidates suggested that the "velocity of light should be kept constant". As indicated in previous reports the word "controlled" is not an acceptable alternative to "constant". This mark is assesses the understanding of fair testing.

Five marks are available for the methods of data collection. Candidates are expected to draw a labelled diagram of the arrangement of their equipment suitable for this investigation. It was expected that candidates would indicate how the light sources would produce monochromatic light. Often candidates copied the diagram from page 2 without adding any additional detail. Many of the diagrams failed to indicate monochromatic sources of light. Examiners allowed a label showing colour filters, an LED or a laser as being sufficient at this stage. The methods used to find the wavelength of light from the two sources were not well known. Diffraction methods or Young's slits were expected, but equally a full statement about a label on the filter or LED/laser could be given credit. Some weaker candidates attempted to find the frequency of the light with a c.r.o., while others claimed that varying the frequency of the electrical supply to a bulb would change the wavelength of light emitted. An additional detail mark could have been scored for explaining how the wavelength of the light was determined by carrying out diffraction experiments or Young's slits experiments.

The value of the angle subtended by the two light sources when they merge is very small and so the Examiners were expecting a trigonometric approach to measure the angle—protractor methods were not allowed. It was expected that the candidates would clearly identify the distances to be measured and how they would be measured. Candidates were also expected to indicate how the distances would be used to determine the angle correctly. The final mark in this section was for a comment about the need for a darkened room in which to carry out the experiment.

There are two marks available for the analysis of the data. It is expected that candidates state the quantities that should be plotted on each axis of a graph for the first mark, which many candidates did correctly. The second mark was awarded for explaining that the relationship would be valid if a straight line passing through the origin was produced. This needed to be explicitly stated and credit was not given for a sketch graph. Candidates who did not score the second mark often did not realise that the relationship would only be valid if a straight line passing through the origin was produced. Some candidates did not state that the line had to be straight.

There was one mark available for describing an appropriate safety precaution. Candidates should be encouraged to ensure that the safety precaution(s) is relevant to the experiment and both a solution and a problem are clearly reasoned; vague answers did not gain credit. Creditworthy responses linked the heat generated in the sources to an appropriate precaution. Alternatively a comment about possible damage to eyes required dark glasses for the solution. A mark was not awarded for simple references to laboratory goggles.

There are four marks available for additional detail. Candidates should be encouraged to write their plans so as to include full appropriate detail; often candidates' answers pointed to a lack of practical experience. Vague responses did not score.

In addition to the points already mentioned above, credit was also given for:

- use of vertical filament lamps or narrow slits;
- methods to increase the accuracy of measurement of the small angle such as measuring the separations with vernier calipers and using large distances/separations;
- the use of only one eye to view the convergence;
- methods to keep the distances involved perpendicular to one another ("always ensure" distances are perpendicular was not sufficient);
- taking many readings of the angle for each wavelength and then obtaining an average value.

Once again it must be emphasised that those candidates who have followed a 'hands on' practical course during their studies are much better placed to score these additional detail marks. It is essential that candidates' answers give detail relevant to the experiment in question rather than general 'textbook' rules for working in a laboratory.

Question 2

In this data analysis question, candidates were given data concerning the maximum velocity of an oscillating trolley.

(a) This was generally well answered.

(b) Most candidates correctly completed the table of results, finding values for $1/M$ and v^2 and the uncertainty. Many candidates recorded their values to an inappropriate number of significant figures; it is expected that for each row of the table the number of significant figures in the calculated quantities should be the same as, or one more than, the number of significant figures in the raw data. Thus in the first row, M was given to 2 s.f., so $1/M$ should have been given to 2 s.f. or 3 s.f. In subsequent rows, M was given to 3 s.f. so $1/M$ should have been given to 3 s.f. or 4 s.f. The absolute uncertainties in v^2 were often not calculated correctly. To determine the maximum value of v^2, candidates should have taken the largest value of the length of the card (5.1 cm) and the smallest value of time; similarly to determine the minimum value of v^2, candidates should have taken the smallest value of the length of the card (4.9 cm) and the largest value of time.

(c) (i) Common mistakes included not plotting the points correctly (particularly the point at 0.571 for the $1/M$ value which was often plotted at 0.56 or 0.58). Candidates should be advised to ensure that the size of the plotted points is small; large 'blobs' were not credited. Candidates should be encouraged to check points that do not appear to follow the line of best fit.

(ii) Most candidates attempted to draw and label the line of best fit. However, the Examiners did not consider the line from the first to the last points to be the best; candidates should be encouraged to have a balance of points about their line. The worst acceptable straight line should be either the steepest possible line or the shallowest possible line that passes through the error bars of all the data points used for the line of best fit. Some candidates are not completing the line from their plotted point to their error marks (a vertical line in this case) which makes it difficult to draw the worst acceptable line correctly. The majority of the candidates labelled clearly the lines on their graph; lines not identified may be penalised in the future.

(iii) This part was generally answered well, although candidates could often make their working clearer. Some candidates did not use a sensibly-sized triangle for their gradient calculation. To determine the absolute error in the gradient, candidates were expected to find the difference between the gradient of the line of best fit and the gradient of the worst acceptable line. A large number of stronger candidates clearly indicated the points that they have used from the line of best fit.

(d) (i) Most candidates scored a mark for correctly using their expression for gradient from **(a)**. Substitution methods were not credited. The second mark was awarded for the correct unit.

(ii) The percentage uncertainty in k must be obtained from the gradient of the graph and the initial displacement A. Therefore the value must be at least 5% and many candidates did this correctly.

(e) Candidates needed to find the maximum velocity and its uncertainty when the initial displacement was reduced to 0.100 m and the total mass of the trolley system was 0.75 kg. Many candidates gained these two marks. Some candidates did not give their final answer to an appropriate number of significant figures. Candidates were able to use any appropriate method to determine the absolute uncertainty in this value of v. Stronger candidates used half the uncertainty in their value for k together with the uncertainty value for A. However, the Examiners allowed different methods for finding uncertainties provided the working was clearly set out. A number of the methods are to be found in the Mark Scheme.

It is essential that candidates clearly show their working, particularly to questions such as **(d)(ii)** and **(e)**. Candidates should also be clear as to their understanding of percentage uncertainty and absolute uncertainty.