

PHYSICS

Paper 9702/11
Multiple Choice

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

General comments

This paper demands quick and accurate working. Candidates should be advised never to spend a disproportionately long time on any one question, at least until they have finished nearly all of the questions. Candidates must be encouraged to work through many questions. There is plenty of space for working on the paper which can be used for this purpose. Care with units is essential. Prefix errors are a cause of many wrong answers as are corresponding power of 10 errors. Candidates must be certain to look critically at any answer they give to see if it makes basic sense.

Comments on specific questions

Question 1

This question tested straightforward recall but many candidates did not choose the correct answer.

Question 2

This type of routine question needs to be practised more carefully, not only for the multiple choice paper but also for the written papers. Candidates often do not notice impossibly incorrect answers because of incorrect units or powers of ten.

Question 5

Many candidates did not double the percentage uncertainty in the diameter.

Question 6

Many candidates assumed that the horizontal component of the velocity was constant. These candidates would have benefited from careful reading of the question, noting that “air resistance is **not** negligible”.

Question 7

A common mistake was to choose **B**. Candidates choosing **B** correctly calculated the time for the object to reach its maximum height, but then did not double this to give the total time taken to return to its starting point.

Question 11

The forces R_1 and R_2 are always equal to the weight of the picture, so only **A** and **B** have a correct statement involving these forces. Consideration of the angles shows that $T_1 > T_2$, or alternatively candidates could simply rule out **A** by reasoning that T_1 and T_2 cannot be equal.

Question 15

It is likely that many candidates would have realised that Wq was the gain in potential energy, but many candidates chose Wr as the work done. These candidates should be encouraged to remember that the work done is the change in potential energy, or alternatively that work done = force \times distance moved in the direction of the force.

Question 18

It is worth emphasising to candidates that the molecules in a solid and those in a liquid have similar spacing. Ice is slightly less dense than water at 0 °C (it floats on water), so its molecules are slightly further apart than molecules in water.

Question 21

Candidates found this question difficult. Some candidates forgot g and some seem to have ignored the gradient of the line (i.e. that the load is not constant). A direct way to reach the answer is to use $(2.85 \times 9.8 \times 0.01) = 0.28$.

Question 24

The manipulation of this equation into $f^2 = g/2\pi\lambda$ caused problems. A large number of candidates gave the incorrect answer **C**.

Question 29

Answer **C** was common, and this showed a similar misunderstanding to **Question 15**. As the charge moves from P to Q, the force is always at right-angles to the motion, and so no work is done, giving **A** as the correct answer.

Question 31

Candidates found this question difficult. The energy transferred in the external resistor is I^2Rt which gives 24 J. The battery must therefore supply a total of 30 J of energy to the whole circuit. The charge transferred is It (= 2.4 C) and so the e.m.f. of the battery is $(30 \text{ J} / 2.4 \text{ C}) = 12.5 \text{ V}$, answer **D**.

Question 33

The resistance of the ammeter has no effect because the voltmeter is connected to measure the potential difference across only the fixed resistor. The voltmeter must have a much greater resistance than R , otherwise there will be a significant current in the voltmeter and the value obtained from V/I will not be an accurate value for R .

Question 36

This question requires careful thought. The two 'corners' of the circuit each have resistance 32Ω , so their combined resistance in parallel is 16Ω . This is in parallel with the diagonal of resistance 16Ω , so the total resistance must be 8Ω , answer **A**.

Question 39

The nucleus contains 235 nucleons. A neutral atom would have 92 electrons, but this atom is doubly-ionised and positive, so it must have 90 electrons. There are 325 particles in total, answer **B**.

PHYSICS

Paper 9702/12
Multiple Choice

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

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Comments on specific questions

Question 5

Almost half of the candidates assumed that the uncertainty was $0.5\text{ }^{\circ}\text{C}$ in the temperature difference of $60\text{ }^{\circ}\text{C}$, but this is only half of the uncertainty since this happens at both the low and the high temperatures. The correct answer is **D**.

Question 6

Many candidates chose **C**. These candidates had determined the average speed. The question asked for the average velocity, which is zero: the car starts and finishes at the same point. Candidates should be encouraged to read the question carefully. In this case, there is a significant difference between speed and velocity.

Question 10

This question involves equilibrium of an object moving with constant velocity. The resultant force on the trailer is zero, so the force exerted by the tractor on the trailer is 1000 N. This is equal and opposite to the force exerted on the tractor by the tow-bar.

Question 12

Most did the arithmetic of this question correctly, but many candidates did not take into account the fact that the arrows on an electric field diagram show the direction of the force on a positive charge. Here the charge must be negative.

Question 15

This is more easily seen in terms of kinetic energy. When the mass is at R, it has half the final speed so has gained energy $E/4$. This is when it has lost potential energy $E/4$.

Question 16

The gain in potential energy per second depends on the vertical distance moved per second. Two common mistakes were to use 60 m rather than 30 m and forgetting to add on the 2.0 kW.

Question 24

This question was found to be difficult. Candidates would benefit from drawing on the exam paper. If they did draw a wave, at most a tenth of a wavelength further on, they would have seen that at **A** and **B** the water is moving downwards. At **D** it is just slightly upwards but the answer is clearly **C**.

Question 29

The field is uniform and so the electrical potential energy decreases uniformly with distance. The kinetic energy therefore increases uniformly too, which is answer **D**. This answer could also be obtained by reasoning that a constant force gives a constant acceleration, and then using $v^2 = 2ax$ shows that the kinetic energy is proportional to x . Many candidates may have assumed that the horizontal axis represents time, and these candidates would have benefited from more careful reading of the question.

Question 32

Candidates found this question to be one of the most difficult on the paper. If the pump performs acceptably, the potential difference across the pump is 218 V, so the potential difference across the cables is 12 V. The current is 0.83 A so the cables have a total resistance of 14.5 Ω . The total length of the cables is 36 m, giving a resistance per unit length of 0.40 $\Omega \text{ m}^{-1}$, which is answer **A**.

Question 33

This question can be answered using Kirchhoff's second law: $(2.0 \text{ V} - 1.6 \text{ V}) = (2.0 \Omega + 0.8 \Omega + 1.2 \Omega)I$. Candidates must take care with the signs of the e.m.f. terms.

Question 35

The potential difference across PS is given by $2.000 \text{ V} \times (0.400 \times 5.00 \Omega / [R + 5.00 \Omega])$. Equate this to the e.m.f. of the solar cell and rearrange to obtain R , which is 795 Ω , answer **B**.

Question 38

Some candidates gave **D**. The mass cannot be conserved because the decay releases energy. The correct answer **C** can be obtained by carefully writing out the nuclear equation with correct proton numbers for the alpha and beta particles, and this shows no overall change in proton number.

PHYSICS

Paper 9702/13
Multiple Choice

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2	D	22	D
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11	B	31	A
12	C	32	C
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Comments on specific questions

Question 1

Many candidates chose answer **B**, perhaps connecting “electro...” or “...volt” in the stem with the electrical answers.

Question 10

Candidates found this question difficult. The table does not exert any force on the ball at the instant they make contact or at the instant they separate. The force must gradually increase and then decrease between these points, so only **C** could be correct.

Question 12

This question needs care. The speed of m is twice the speed of $2m$ because momentum is conserved. The kinetic energy of m is therefore multiplied by 4 as a result of the v^2 term and divided by 2 because it has half the mass. This gives answer **C**.

Question 14

This question is unusual and candidates found it difficult. The energy required depends on working out the rise in potential energy when the cuboid's bottom right edge is the only contact with the ground and the top left edge is vertically above it. This gives a 5, 12, 13 triangle and the centre of mass is then 0.65 m above the surface.

Question 16

Candidates also found this question difficult. The efficiency η is given by $P_{\text{out}} = \eta P_{\text{in}}$. The power lost P_{lost} is given by $P_{\text{lost}} = P_{\text{in}} - P_{\text{out}}$. Algebraic manipulation gives the answer **D**.

Question 18

Kinetic energy is a scalar so does not have a direction, so **D** cannot be the correct answer. Some candidates chose **C**, but this cannot be correct because the ball stops (during which time all the energy becomes elastic potential energy).

Question 19

Water expands when it freezes and becomes ice. This should have enabled candidates to rule out options **A** and **B**.

Question 22

Some candidates found this difficult. The formula for pressure is given in the question paper, and candidates should be reminded to use the formulae given rather than relying on memory.

Question 26

This was a somewhat different question but the syllabus does require candidates to know the orders of magnitude of the wavelengths of different components of the electromagnetic spectrum. Candidates should also be able to change these to frequencies.

Question 31

The force on the electron is opposite to the direction of its motion. This causes deceleration but the path will be linear, so the answer is **A**.

Question 34

Replacing the cell with a different cell with negligible internal resistance gives half the total resistance, so double the current. The power dissipated in the external resistor is I^2R , so it must increase by a factor of 4, giving **D**.

Question 35

The current is obtained from the e.m.f. and the total resistance, and is 3.0 A. The power in the heater is given by I^2R , which is 27 W, answer **A**.

Question 36

Candidates found this question difficult. W and X will give identical graphs. In each of these arrangements, the resistance of the length d of the potentiometer is connected into the circuit but the right-hand end does not contribute.

Question 37

The answer to this question can be reasoned by symmetry. The junctions on either side of the $40\ \Omega$ resistor must be at the same potential, so there is no current in this resistor.

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<p>Paper 9702/21 AS Structured Questions</p>
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Key messages

- The use of precise terms in physics is important when stating definitions and explaining phenomena. Candidates at this level should be encouraged to use the correct words or terms in formal definitions. Language that is often acceptable in everyday speech does not necessarily convey correct meanings. For example, in physics, there are clear differences between distance and displacement, speed and velocity.
- Candidates should be encouraged to start numerical questions with the defining equation and give their working at each stage. In this way partial credit can be awarded if the final answer is incorrect.
- Power-of-ten errors are a relatively common cause of lost credit. Candidates should be encouraged to take a moment to consider whether their answers are of a reasonable order of magnitude, as this check can often detect mistakes with powers-of-ten or arithmetic.

General comments

The marks scored by candidates varied over almost the whole mark range. There were parts of some questions that were testing. Well-prepared candidates were able to show their understanding of the relevant concepts. Other parts of questions were straightforward and allowed weaker candidates to gain credit. In descriptive questions many candidates would have benefited from having more thorough knowledge and understanding to give accurate and precise answers.

It should be remembered that a proportion of the marks are dedicated to application and extension of the basic content of the syllabus. In order to score highly, candidates do need to have a thorough understanding of the subject matter.

Comments on specific questions

Question 1

- (a) (i) Velocity should be defined in terms of rate of change of displacement. In many scripts, reference was made to 'distance moved'. Where a ratio is involved, as in this case, candidates should be discouraged from using loose wording such as 'over time'.
- (ii) Rather than refer to 'magnitude' and 'magnitude and direction', many candidates gave their answers by categorising the quantities as a scalar or a vector. Stating that velocity is 'speed in a given direction' does not distinguish clearly between the two.
- (b) (i) In nearly all answers, reference was made, in some way, to area under the line on the graph. However, many candidates did not use the correct area. Candidates should be encouraged to read the question carefully (noting here that the relevant time is 'when the brakes are applied').
- (ii) A small minority thought that the weight of the car would be the resultant force. Most candidates did calculate a value for the acceleration and then substitute this into the relevant equation.
- (c) It was common to see the two arrows pointing in opposite directions. Candidates should be reminded that resultant force and acceleration are always in the same direction.

Question 2

- (a) (i) Candidates should appreciate that power involves a transfer of energy. Thus, power should be defined in terms of energy transfer or work done, not just 'energy'.
- (ii) In any derivation, it is important to explain the working, especially the symbols used. It was very common to find that this derivation was completed using symbols without explanation, or that non-standard symbols were used rather than those listed in the syllabus.
- (b) (i) There were many good answers produced by well-prepared candidates. With few exceptions, it was realised that the weight, rather than the mass, of the lorry should be considered. Weaker candidates often did not appreciate that it is the component of this weight acting down the slope that is relevant.
- (ii) There were very few answers where reference was made to constant kinetic energy because the speed is constant. Some stated that the kinetic energy would be zero. Likewise, very few candidates stated that no work would be done against air resistance. In a significant number of scripts, the answer was given as 'constant speed with no air resistance'. It should be emphasised to candidates that paraphrasing the question does not score any credit.

Question 3

- (a) (i) There were very few complete answers and many candidates merely stated that 'upward forces equal downward forces'. Candidates should be advised to use more precise terminology. Stronger candidates discussed the direction and summation of the various forces.
- (ii) Candidates who had practised this type of calculation generally scored well. There appeared to be candidates who had not dealt with situations where a beam is supported in two positions and had perhaps concentrated only on beams balanced on pivots. Candidates should appreciate the significance of taking moments about a point through which an unknown force acts.
- (b) Most lines were drawn correctly and with a ruler.

Question 4

- (a) This calculation, based on the expression for kinetic energy, was completed successfully by most candidates.
- (b) (i) There were many answers correctly based on the expression $F = kx$. A significant minority equated force to kx^2 .
- (ii) Many answers involved a correct calculation of the elastic potential energy. However, in many scripts, the candidates left the answer without comment. It was expected that a statement would be made, comparing the answer obtained with the kinetic energy in (a).

Question 5

- (a) Some candidates lost credit as a result of imprecise terminology. This is relatively common in questions on waves. Candidates would benefit from learning the meanings of terms used to describe waves in more detail.
- (b) (i) 1. The amplitude was often quoted as 3 mm, rather than 1.5 mm.
2. The majority of candidates recognised that there are 6 wavelengths in 25 cm but power-of-ten errors were common.
- (ii) The majority of answers were correct. Some candidates showed confusion between time period and frequency.
- (c) (i) In most scripts, the wave was correctly identified as being progressive, with a reference to energy transfer.

- (ii) The great majority of answers included a reference to transverse waves. However, the reasoning was frequently inadequate. Candidates were expected to state that the direction of the vibrations is normal to the direction of travel of wave energy. Inappropriate statements such as 'the particles move at right angles to the direction of the wave' were common.

Question 6

- (a) Many answers did not make reference to energy changes. Where energy changes were identified, few went on to state that both e.m.f. and p.d. are defined in terms of some form of energy change per unit charge.
- (b)(i) Stronger candidates who understood electrical circuits were able to give an adequate answer referring to either internal resistance or 'lost volts'.
- (ii) In general, this calculation was completed successfully.
- (iii) There were very few correct answers. The great majority of candidates divided the e.m.f. of the battery by its internal resistance, rather than the total resistance of the circuit.
- (iv) Candidates found this part difficult, even allowing for error-carried-forward from an incorrect answer in (iii). The value of the current was often taken as the current from the battery, rather than the current in an individual lamp.
- (c) Candidates who had an understanding of this topic usually gave a good explanation. Some thought that an additional lamp would increase the resistance of the circuit. Of those who stated that the total resistance would decrease and that the current would increase, many then incorrectly stated that the terminal p.d. would increase. Candidates should be reminded that increased current in a battery with internal resistance results in a lower terminal p.d.

Question 7

- (a) In many answers, α -particles were stated as being helium ions or particles. It is more precise to refer to helium nuclei. Similarly, γ -radiation was often said to be 'energy', whereas a more precise answer is to say that it is electromagnetic radiation or photons.
- (b) In general, correct answers were given to all parts of this question.

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<p>Paper 9702/22 AS Structured Questions</p>
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Key messages

- The use of precise terms in physics is important when stating definitions and explaining phenomena. Candidates at this level should be encouraged to use the correct words or terms in formal definitions. Language that is often acceptable in everyday speech does not necessarily convey correct meanings. For example, in physics, there are clear differences between distance and displacement, speed and velocity.
- Candidates should be encouraged to start numerical questions with the defining equation and give their working at each stage. In this way partial credit can be awarded if the final answer is incorrect.
- Power-of-ten errors are a relatively common cause of lost credit. Candidates should be encouraged to take a moment to consider whether their answers are of a reasonable order of magnitude, as this check can often detect mistakes with powers-of-ten or arithmetic.

General comments

The marks scored by candidates varied over almost the whole mark range. There were parts of some questions that were testing. Well-prepared candidates were able to show their understanding of the relevant concepts. Other parts of questions were straightforward and allowed weaker candidates to gain credit. Candidates were generally competent in dealing with calculations, although a common cause of incorrect answers was in power-of-ten errors. In descriptive questions many candidates would have benefited from having more thorough knowledge and understanding to give accurate and precise answers.

It should be remembered that a proportion of the marks are dedicated to application and extension of the basic content of the syllabus. In order to score highly, candidates do need to have a thorough understanding of the subject matter.

Comments on specific questions

Question 1

- (a) The majority of candidates were able to obtain at least partial credit. The question is a 'show that' question and this requires full details of the working. Common reasons for not obtaining full credit were not giving a defining equation for power or not showing how the units for each quantity in an acceptable equation were obtained. In this type of question, candidates should be encouraged to give the base units for each term in the equation and not to miss out critical steps.
- (b) Many candidates did not recognise that the energy/time in this part had the same base units as those given in (a). A significant number started from an equation for energy or left the units as J s^{-1} rather than base units. There were also a significant number who did not read the stem of the question carefully and gave the base units of Q/t as A (ampere). Some candidates used $^{\circ}\text{C}$ for temperature instead of the base unit K. Well prepared candidates seemed to have little difficulty in obtaining the correct base units. In this type of question candidates should be encouraged to start with the base units for each term in the equation and not to miss out critical steps.

Question 2

- (a) The vast majority of candidates started with the correct equations for density and volume. The major errors were in powers-of-ten, not squaring the radius or using the diameter as the radius. There were a significant number of candidates who calculated the correct value for the density.
- (b)(i) The majority of candidates found this part difficult. A significant proportion of candidates did not seem to understand the process for calculating a total percentage uncertainty. Common mistakes were to give the fractional uncertainty instead of the percentage uncertainty and not including all the quantities used to calculate the density. Many candidates did not use twice the percentage uncertainty for the diameter or used the same uncertainty in the radius as was given for the diameter.
- (ii) Many candidates found this part difficult. The majority of answers gave two or more significant figures for the uncertainty or an answer for the density that did not have a value to the same decimal place as the uncertainty.

Question 3

- (a) Many candidates were imprecise in this definition. The majority omitted constant speed in a straight line or the resultant external force.
- (b)(i) Many candidates gave imprecise directions for the two forces or no directions at all. A normal force upwards and a weight downwards were considered to be given with insufficient detail, as it is unclear whether “up” and “down” refer to the slope or to the vertical.
- (ii) 1. A correct derivation was given by the vast majority of candidates. Very few candidates misread the graph axes.
2. The correct answer was given by the vast majority of candidates. A small minority gave the component of the weight down the slope and therefore had not related the acceleration in **(ii) part 1** to the resultant force.
3. A significant number of well prepared candidates were able to complete this calculation correctly. The average candidate found this part very demanding. The component of the weight down the slope was often either not calculated correctly or $g = 10$ was used. The signs used for the directions of the two forces acting caused a problem and some included the resultant force calculated in **(ii) part 2** together with ma in their equation. There were some solutions that merely equated the resistive force with the weight component.

Question 4

- (a) The majority of candidates scored the mark for their explanation of kinetic energy. There were few correct explanations of gravitational potential energy. The lack of precision generally included using “body” instead of mass and omitting the need for a gravitational field. Candidates should be encouraged not to merely give an equation when an explanation is required.
- (b)(i) 1. Most answers were correct. The most common errors were in the power-of-ten conversion of the mass, using the vertical component of the velocity or giving the correct equation but then not squaring the velocity.
2. A significant number of candidates showed a basic misunderstanding of this type of motion. The common errors were to use the initial velocity instead of the component in the vertical direction, to equate the loss in kinetic energy with the gain in potential energy or to use a positive acceleration.
3. The majority of candidates completed the calculation successfully. Many were awarded credit despite an incorrect **(i) part 2** by the application of error carried forward.
- (ii) 1. There were a large number of correct answers with candidates using either the horizontal component of the initial velocity or by subtracting answers to **(b)(i) part 3** from **(b)(i) part 1**. Credit was obtained by many candidates by the application of error carried forward. Candidates were not awarded credit where a potential energy value was used which was greater than the original kinetic energy and no comment was made.

2. There were a significant number of correct answers where candidates realised that the ball continued to move as it went through the maximum height. Stronger candidates went on to say that the horizontal component remained constant.

Question 5

- (a) The vast majority of candidates gave the correct answer.
- (b)(i) A large number of candidates were successful in completing this calculation. There were a significant number of candidates who were unable to solve the fractions obtained. There was also some confusion when calculating the area, using the diameter instead of the radius or not squaring the radius / diameter.
- (ii) The majority of candidates found this part very difficult. Very few realised that, as the wires were made from the same material, the value of the Young modulus would be the same. Candidates should be encouraged to think of the Young modulus as a property of a material itself, rather than being a property of a sample with specific size or shape. A significant number of candidates gave an answer without the necessary working.

Question 6

- (a) The majority of candidates were able to give the correct answer.
- (b) A significant number of candidates understood that, if the current decreases in the circuit, the potential difference across Y must decrease. Many candidates did not use the graph that showed the current decreasing with increasing R . There were many misinterpretations of the circuit which often came as a result of not reading the circuit or text carefully. The effect of R increasing was used in the equation $V = IR$ to suggest that the p.d. would increase. The fact that there was an effect on the current of increasing R and that the V required was not that across R was missed by many of these candidates.
- (c)(i) The majority of candidates answered this correctly. The candidates who obtained the current in the circuit from the graph usually went on to complete the calculation. There were many attempts to work backwards from the answer but this was generally unsuccessful.
- (ii) The majority of candidates found this calculation difficult. The determination of the resistance using the parallel formula caused most candidates a problem. A significant number of candidates determined the correct resistance for the parallel section but then found it difficult to determine the resistance of X or gave this answer as the resistance of X . There were some good answers from the stronger candidates.
- (iii) The majority of candidates were able to quote a correct formula for power. The second mark was awarded to those candidates who understood that the total voltage, the circuit current or the circuit resistance was required. A significant minority were able to complete this calculation successfully.
- (d) There were very few correct answers. Many candidates did not comment on the e.m.f. of the battery remaining constant.

Question 7

- (a) The answers often lacked the detail required at this level. 'Rays' or 'light' were terms often used instead of waves. Candidates should be encouraged to use correct terms when asked for an explanation. The need for the waves to be coherent after passing through the slits was seldom described by candidates. The description of 'crest on crest' for a maximum is not sufficient at this level. A description involving path or phase difference between the waves that reach the screen should be encouraged. There were a significant number of candidates who confused path and phase difference. Repeating the words in the question without any further explanation will not gain any credit and should be discouraged.
- (b) The vast majority of candidates gave a correct solution.

- (c) The majority of candidates started with the correct formula. Many candidates did not divide the distance given on the screen by any number (or the wrong number) to obtain the fringe width. Careful examination of the diagram shows that the 12 mm length is not the fringe width.
- (d) The majority of candidates gave the correct description and explanation.

PHYSICS

<p>Paper 9702/23 AS Structured Questions</p>
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Key messages

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Comments on specific questions

Question 1

- (a) A considerable number of answers included the base units instead of the base quantities. A significant number considered charge to be a base quantity. Mass was frequently omitted from the list of correct answers.
- (b) A significant number of candidates were able to determine the required base units. Incorrect answers were often obtained due to lack of knowledge of the base units for energy and strain. Other mistakes included incorrect rearrangement of the equation, poor presentation of the base units for each separate quantity and careless cancelling of powers.

Question 2

- (a) A large majority referred to 'magnitude' and 'magnitude and direction', to distinguish between scalars and vectors. Incomplete answers merely gave the 'direction' as being relevant to a vector but not to a scalar. Weaker candidates replaced magnitude with distance or displacement and some merely gave an example of each.
- (b)(i) A relevant equation of constant acceleration was correctly used by most candidates to determine the vertical velocity.

- (ii) A relevant equation of constant acceleration was used successfully by most candidates.
- (iii) Candidates who had practised this type of calculation generally scored high marks. A considerable number of candidates were unable to calculate the horizontal displacement of the ball. Many used an equation of constant acceleration. The idea that the displacements in the horizontal and vertical directions could be treated independently was missed by a large majority of candidates.
- (iv) Many answers did not relate to the question and merely gave vague statements of distance and displacement. Descriptions of the distance as the length travelled along the actual path of the ball, the curved path, and displacement as the straight line path were made by only a small minority of candidates.

Question 3

- (a) Many candidates gave an answer that was not sufficiently precise at this level. The explanation should refer to a force moving a body in the direction of the force. Work done being described merely as the 'product of force and distance' does not gain credit (this could also describe a moment).
- (b)(i) Very few candidates followed the instruction to give a word equation in terms of the quantities work done, change in kinetic energy and change in potential energy. Those that did were often not specific with the sign of the change for the kinetic and potential energies, and hence it was not clear whether the change was a gain or a loss.
- (ii) 1. The majority obtained the correct answer by referring to the area under the line on the graph. Correct answers also resulted from candidates determining the acceleration from the gradient of the graph and then using an equation of constant acceleration.
- 2. In general this calculation was completed successfully.
- 3. The majority of candidates gained at least partial credit by giving the equation. The well prepared candidates were able to determine the height fallen and the correct answer for the loss in potential energy. A significant number of candidates found this to be more challenging and merely used the distance moved down the slope.
- 4. A significant number of candidates were able to complete this part correctly by equating the work done to the energy loss. There were some candidates who calculated the acceleration and the component of the weight down the slope. They then equated the resultant force with the product of mass and acceleration. A considerable number found the solution difficult and appeared not to be familiar with this type of situation.

Question 4

- (a) Very few candidates described a method of determining the load at the elastic limit. A majority described how the limit of proportionality or Hooke's law could be determined. There were a small number who described adding loads in small amounts and removing the load at each stage to see if the spring returned to its original length.
- (b) The majority of candidates correctly thought that the graph showed that the spring obeyed Hooke's law. A significant number were unable to justify their proposal. A statement of Hooke's law was expected. Many suggested that the graph showed that the mass was proportional to the reading x and that this demonstrated the law.
- (c) A significant majority gave the correct equation for the force constant. The solution was then often carried out incorrectly as a value of x was used instead of a value for the extension. Common mistakes were not converting the units for extension to metres and/or the mass into a force.

Question 5

- (a) There were numerous answers that did not make reference to energy being used in the battery or 'lost volts' in the battery due to the internal resistance. There were very few answers that added that this only occurs when the battery supplies a current. The idea that the terminal potential difference is numerically equal to the electromotive force when the battery is not supplying a current was seldom mentioned.
- (b)(i) The majority of candidates were able to complete this calculation correctly. A significant number calculated the total circuit resistance.
- (ii) The majority of candidates were able to complete this calculation correctly. Some candidates calculated the potential difference across the internal resistance of the battery (the 'lost volts').
- (iii) Most candidates were able to complete this calculation correctly. A significant number calculated the power dissipated in the internal resistance or the total resistance in the circuit.
- (iv) The majority of candidates were able to complete this calculation correctly. A significant number seemed to be unfamiliar with this type of calculation and were unable to use the information given in the question to calculate an appropriate efficiency for the battery.
- (c) Candidates with an understanding of this topic generally gave a good explanation. There were many who thought that the addition of a resistance in parallel would increase the total resistance of the circuit. Some descriptions indicated a lack of understanding of the effect of a change in resistance in a circuit with a heating effect in the battery.

Question 6

- (a)(i) The majority of candidates correctly identified the difference between progressive and stationary waves. A significant number of answers were incomplete with only a statement about the progressive wave being given.
- (ii) There were many answers that described the general formation of stationary waves without any reference to the situation in the question. Candidates should be encouraged to describe phenomena with specific reference to the question. Very few candidates gained full credit for this part.
- (iii) A small minority of candidates recognised that the stationary wave in this question had been formed by a sound wave and that the vibration of particles was parallel to the length of the tube.
- (b) The majority of answers were correct. A common omission was the node at the fixed end of the tube.
- (c) The concept of phase difference within a loop of a stationary wave was poorly understood by the majority of candidates. Candidates would benefit from further study of the phase relationships in a stationary wave.
- (d)(i) The vast majority of candidates calculated the wavelength correctly.
- (ii) The majority of candidates correctly calculated the length of the tube. Some candidates made a mistake in determining the number of wavelengths shown in Fig. 6.1.

PHYSICS

Paper 9702/31

Advanced Practical Skills 1

Key messages

- When preparing the graphical work in **Question 1**, candidates should choose scales for their axes to enable ease of use. This helps in the plotting of points and reading off of coordinates for the gradient and intercept values.
- In the graphical work in **Question 1**, candidates should be encouraged to use a sharp pencil and a transparent 30 cm ruler in order to plot points and draw an appropriate line of best fit. When judging where to place the line of best fit, they should consider the balance of all the points about the line along the entire length. Candidates should be dissuaded from joining the first and last points without considering the balance of the rest of the points, and should also be advised not to force a line through the origin regardless of the position of the points.
- When estimating uncertainties, candidates need to consider the limitations of the experiment and not just the smallest possible reading of the measuring instrument.
- To score highly on **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. General points such as “avoid parallax error” or “use more precise measuring instruments” will not usually gain credit without further detail.

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 a 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. 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 extension of a spring varied as the mass hanging from the system changed.

Successful collection of data

- (a) Most candidates measured a value of L_0 and noticed the unit was given as metres, and the value given was in range. Many of those who failed to gain credit appeared to measure the coil without the loops. Candidates were able to gain credit for values of L_0 outside the expected range if the

Supervisor's Report gave dimensions of a different spring, so it is vital that Supervisors provide this information.

- (b)(iii) Most candidates were able to set up the apparatus correctly. Candidates who were familiar with using and manipulating clamps and stands coped well with the adjustments needed. The majority of candidates measured the length L which was larger than L_0 .
- (c) Most candidates were able to collect six sets of values for m and L so that as m increased, L decreased. Some candidates took readings such that L increased as m increased, giving rise to an incorrect trend. This suggested that the instructions had not been followed carefully.

Range and distribution of values

- (c) Candidates should look at the range available to them and spread out the readings to make full use of the whole range. The initial value of m was 0.200 kg. The most common range used was 0.200 – 0.250 kg, i.e. most candidates did not consider reducing the mass from its initial value. Candidates should have taken readings for masses below and above 0.200 kg.

Presentation of data and observations

Table

- (c) Many candidates were able to include a quantity with correct units in the column headings. Some candidates forgot that when a quantity is squared the unit is also squared so m^2/kg^2 and e^2/m^2 would be correct. Candidates need to remember to include the quantity and a separating mark, such as a solidus, between the quantity and unit.

Some candidates correctly stated the raw values of L to the nearest mm, e.g. 0.094 m. Many others needed to take account of the precision of the metre rule, as they recorded answers to the nearest cm, e.g. 0.09 m; here the candidate needed to record the reading as 0.090 m. Some candidates lost credit when they added an extra zero and stated L values to the nearest tenth of a mm e.g. 0.0940 m.

Most candidates were able to calculate e^2 correctly. Many of the errors in the calculations were due to incorrect rounding. Candidates should give the value of m^2 to a consistent number of significant figures based on their value of m . A common misunderstanding is with 0.200 kg which has 3 significant figures; m^2 in this case should be recorded as 0.0400 **not** 0.04.

Graph

- (d)(i) Candidates were required to plot a graph of e^2 against m^2 and gained credit for drawing appropriate axes with labels and sensible scales. Candidates should keep in mind that the scales should be easy to use. Many candidates chose awkward scales that were either linear (going up in threes or sixes) or non-linear showing gaps in the scale (missing out a number), or left gaps of 4 large squares between scale markings. These mistakes also resulted in errors in read-offs of the coordinates used for the gradient and y -intercept calculations. Candidates can improve the suitability of their graphs 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. Candidates should also check that they have labelled their axes and drawn the correct axes (e.g. m^2 drawn and not m). Candidates gained credit for plotting all the tabulated readings to within half a small square.
- (ii) Some candidates were able to draw a good line of best fit through six points. Other candidates gained credit for drawing a line through five trend points with one clear anomalous point identified. If a point is being treated as anomalous for the purposes of drawing the line of best fit, this should be indicated clearly on the graph (although it is recommended that any anomalous point first be checked by repeating the measurement using the apparatus). Only one point, if any, should be identified as anomalous and certainly not two or three. Some candidates need to rotate lines to give a better fit or move the line sideways to give a better balance of points along the entire length of the line.

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). Many triangles used were too small.

A few candidates drew a suitable triangle then stated different read-offs, either from the table or from different points on the graph that were not on the line of best fit. Many candidates showed a correct calculation from their read-offs but ignored the negative sign when in fact the gradient should be negative. Some candidates read off the y -intercept at $x = 0$ directly from the graph, gaining credit. Others needed to check that the x -axis did actually start at $x = 0$ (i.e. no false origin) in order to validate this method. 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 a point from the table.

Drawing conclusions

- (e)** Some candidates recognised that P was equal to the negative value of the gradient and Q was equal to the value of the intercept calculated in **(d)(iii)**. Others ignored the need to change the sign of the gradient value. Some candidates 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 method as the question specifically asks for the answers in **(d)(iii)** to be used.
- (f)** Many candidates used their values for P and Q correctly to find a value for M that was in range, and stated the unit consistently as g or kg . Some candidates tried using the equation to find the unit for M unsuccessfully.

Question 2

In this question, candidates were required to investigate how the motion of a hacksaw blade depends on the position of masses on the blade.

Successful collection of data

- (b)(ii)** Most candidates recorded a value of x with consistent units and in range e.g. 28.0 cm. Some candidates did not gain credit as they omitted the units. Some candidates lost credit by recording x to the nearest cm e.g. 28 cm, or adding an extra zero and recording to the nearest tenth of a mm, e.g. 28.50 cm.
- (c)(ii)** Most candidates recorded a value of T in range and with a correct unit, and showed evidence of repeat values to gain full credit. Some candidates forgot to divide their recorded time by the number of complete cycles undertaken so that their final answer was too large, whilst other candidates timed half a complete cycle instead or misread the stop-watch (e.g. 0.005 s instead of 0.5 s) and stated a final value that was too small.
- (d)(ii)** Most candidates recorded a second value for x and T .

Quality

- (d)(ii)** Most candidates found that, when x was reduced by lowering the masses, the value of the time for the complete cycle also reduced, gaining credit.

Presentation of data and observations

Display of calculation and reasoning

- (c)(iii)** Most candidates were able to calculate f correctly. Errors in the calculations were often due to incorrect rounding in the final value.

- (e) (i) Most candidates were able to calculate $k = f^2 x^3$ correctly for both experiments. Some candidates rounded their answers to one significant figure so that both k values were identical, and this was not awarded credit. A few candidates incorrectly calculated f^2/x^3 .
- (ii) Few candidates were able to relate the number of significant figures in k to the significant figures in x and T . Common mistakes were to relate to just one quantity, to the “raw data” without specifying the quantities, or to the quantity f . Other candidates referred to “the quantity with the least number of significant figures” without stating the actual quantities involved. A few candidates stated a bald “3 s.f.” without any reasoning.

Analysis, conclusions and evaluation

- (e) (iii) Strong candidates compared the percentage difference in their values of k by testing it against a specified percentage uncertainty, either taken from (b)(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. Good answers made a comparison. If the percentage difference between the two k values is less than the stated criterion, the good answers state that the relationship is supported. Candidates should understand that if the value of the percentage difference is greater than the value of the percentage stated as the criterion, then the relationship is not supported and this should be stated explicitly, e.g. “the relationship is not supported”.

Estimating uncertainties

- (b) (iii) Most candidates were familiar with the equation for calculating percentage uncertainty, though candidates found it difficult to make a realistic estimate of the absolute uncertainty in x (2 – 5 mm). Many candidates stated the uncertainty as 1 mm, the smallest reading on the ruler (or 0.5 mm, half the smallest reading on the ruler). Candidates should be reminded that the absolute uncertainty in the value of x 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 x is difficult to judge as it is difficult to judge the location of the centre of the masses, and the starting point in the jaws of the G-clamp is also uncertain. Repeat measurements of x should be encouraged owing to the uncertainty in this measurement. In the case of repeat readings the absolute uncertainty can be calculated as half the range of the repeated values. The calculation should be shown so that it is clear how the estimate of absolute uncertainty has been produced. This method was used by some candidates, though a few of these candidates forgot to halve the range.

Evaluation

- (f) Many candidates scored at least half of the available marks in this section, and the quality of answers has improved. Most candidates were able to state that two readings were not enough to draw a conclusion. Many gained credit for suggesting taking more readings and plotting a graph. Suggesting repeating and averaging does not gain credit, as this could have been done by the candidate. Candidates often stated that the measurement of T was difficult to take with appropriate reasons. They also often stated that it was difficult to measure T accurately since the G-clamp and blade moved as well. 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 T ” is insufficient to gain credit without saying why it was difficult. In this experiment, applying an extra force on release or a variation in the distance the hacksaw blade was pulled back were not relevant.

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 actual difficulties encountered during the experiment, e.g. “difficult to measure T because oscillations have a high frequency”. They can improve their answers by stating the methods used for each solution, e.g. “use a video with a timer to record the oscillations and measure the time for one oscillation”. In doing this candidates should look at how each solution helps and improves this particular experiment. Credit is not given for insufficient detail in procedures e.g. “use a video” (without the need for a timer), “use a video timer” or “use a sensor”. Credit is not usually given for suggesting a change to the equipment which is under investigation, e.g. changing the hacksaw blade to increase the time period.

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Credit is not given for suggestions that should be carried out anyway, such as repeating measurements and calculating averages. General statements such as “parallax error”, “reaction time error”, “use an assistant”, “air resistance” or “performing the experiment in a vacuum” do not gain credit.

PHYSICS

<p>Paper 9702/32 Advanced Practical Skills 2</p>
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Key messages

- When preparing the graphical work in **Question 1**, candidates should choose scales for their axes to enable ease of use. This helps in the plotting of points and reading off of coordinates for the gradient and intercept values.
- When estimating uncertainties, candidates need to consider the limitations of the experiment and not just the smallest possible reading of the measuring instrument.
- To score highly on **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. General points such as “avoid parallax error” or “use more precise measuring instruments” will not usually gain credit without further detail.
- As a general rule, all transient (i.e. non-static) measurements should be repeated two or three times and an average value calculated; likewise measurements which are likely to vary in different places should be repeated. Such measurements could include, for example, the time for an object to fall, or the temperature of an object at a particular time, or the diameter of a roughly-formed sphere of Plasticine. Static measurements, such as the height of a stationary object, or the reading on an ammeter in a circuit, generally do not require repeat readings.

General comments

The general standard of the work done by the candidates was good, with many excellent scripts.

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 a 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.

If a candidate goes back in an experiment and alters an answer, they must ensure that the alteration is clear with the original value crossed out and the new value written above it. Trying to write on top of the original answer is usually confusing and can result in lost credit if the Examiner is unable to read the work. If the quantity has been used in a subsequent calculation, this must also be amended so that it uses the new value.

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

Comments on specific questions

Question 1

In this question, candidates were asked to investigate the equilibrium of a wooden rod supported by a spring.

Successful collection of data

- (a)(i) Most candidates correctly recorded a value for l_0 in the range 4.0 cm – 8.0 cm. Some candidates only measured the length of the coiled section of the spring, recording answers of approximately 2.0 cm, so were not awarded credit.
- (b)(iii) Most candidates recorded a value for h correctly, in the range 40.0 cm – 50.0 cm. A small number of candidates only recorded their answer to the nearest cm. A metre rule, calibrated in mm, should be used to record measurements to a precision of 0.1 cm.
- (c) Almost all candidates were able to set up the experiment, without assistance, and collect six sets of values of h and l , showing the correct trend (l increasing as h decreases). A few candidates obtained results that showed an incorrect trend; others included results where l did not change despite a decrease in h . If candidates choose to record more than the prescribed six sets of values, it is important to note that all the extra points should be plotted on the graph.

Range and distribution of values

- (c) Some candidates recorded at least one value of h less than, or equal to, 20 cm. Others needed to consider using a wider range of values of h to make full use of the apparatus.

Quality of data

- (d)(i) Many candidates were awarded credit for the quality of data. Of those who did not, most had obtained an incorrect (negative) trend on their graph, or had calculated values of $(l - l_0)^2$ incorrectly, taking the first value of l in the table as l_0 rather than the value obtained in (a)(i).

Presentation of data and observations

Table

- (c) Most candidates were awarded the mark for using the correct column headings in their tables, giving both the quantity and suitable units for each quantity, with the two separated by a solidus, or with the units in brackets. Some candidates either omitted the units for $(l - l_0)^2$ or recorded the units for $1/h^2$ as cm^2 rather than cm^{-2} .

The majority of candidates recorded their raw values for h and l 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.

Most recorded the calculated values of $1/h^2$ to an appropriate number of significant figures, though some needed to apply the rule that calculated values should be expressed to the same number of significant figures as, or one more than, the number of significant figures of the raw data used in the calculation (in this case, the values of h).

It is recommended that candidates use standard form whenever possible, particularly when recording very small values—for example, 3.46×10^{-3} is preferable to 0.00346. In this experiment, many candidates sensibly recorded their values for h in cm, which leads to very small values for $1/h^2$.

Most candidates calculated values for $(l - l_0)^2$ correctly, though some used an incorrect value for l_0 , or rounded their answers incorrectly, and were not awarded credit.

Graph

- (d)(i) Candidates were required to plot a graph of $(l - l_0)^2$ against $1/h^2$. Most candidates gained credit for drawing appropriate axes, with labels and sensible scales, though several candidates chose difficult or awkward scales. Scales in the ratio 3:10 were quite common and were not awarded credit.

A few candidates chose their smallest and largest tabulated values for $1/h^2$ as the two values at either end of the scale on the graph paper, interpolating the other points between these two extremes. As well as losing credit for the axes, these candidates often lost further credit later for

incorrect plotting of points or incorrect read-offs when calculating the gradient or intercept. Others chose equally-spaced scale markings to be exactly the same as the values in the table, making the scale non-linear and causing similar problems with plotting and read-offs. Another common mistake was to change scale by a factor of 10 half-way along e.g. 0.07, 0.08, 0.09, 0.1, 0.2, 0.3 etc.

Many candidates gained credit for plotting their tabulated readings correctly. If a point seems anomalous, candidates should repeat the measurement to check that an error in recording the readings/values has not been made. If such a point is ignored in assessing the line of best fit, the anomalous point should be labelled clearly, e.g. by circling the point.

Most candidates plotted their points on the graph paper with great care; others needed to draw the plotted points so that the diameters of the points were equal to, or less than, half a small square (a small pencil cross is recommended). Some candidates can improve by plotting the points more accurately, and by ensuring they use a sharp pencil and a straight ruler.

- (d)(ii)** Some candidates were able to draw carefully-considered lines of best fit, but others often join the first and last points on the graph regardless of the distribution of the other points. There should always be a balanced distribution of points either side of the line.

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). Many triangles used were too small.

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 drawn, 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)**. A few candidates tried to calculate p and q by first substituting values into the given equation and then solving the simultaneous equations, or by repeating the calculations already completed in **(d)(iii)**. No credit is given for this as the question specifically asks for the answers in **(d)(iii)** to be used to determine p and q .

A smaller number of candidates recorded the correct units for p and q . Several candidates either recorded the units for p as m^2 or cm^2 rather than m^4 or cm^4 , or omitted the units for p and q completely.

Question 2

In this question, candidates were required to investigate the motion of a mass and a spring.

Successful collection of data

- (a)(i)** Most candidates recorded a value for d , to the nearest mm, in the range 1.0 to 2.0 cm. Others included an extra zero, implying a measurement to the nearest 0.1 mm, so were not awarded credit. The Examiners can make allowance if a spring with a different length from that specified in the Confidential Instructions is used, but only if the true value is recorded in the Supervisor's Report.

- (b) (ii) The majority of candidates recorded a sensible value for the time t for 10 oscillations though a few candidates misread the stopwatch, recording answers such as 0.06 s (rather than 6 s) – i.e. a number much less than 1.0 s. Fewer candidates repeated their measurements in order to find an average value for t .
- (c) (iii) Most candidates recorded a value for the distance A from the bottom of the mass to the bench, though some needed to take account of the precision of the metre rule by recording their value for A to the nearest mm rather than the nearest cm.
- (e) All candidates were able to record second values for t and A .

Quality

- (f) (i) Some candidates were able to find values of k for which kl was in the range 0.20 to 0.30 cm s^{-2} . Others made power-of-ten errors when substituting values into the equation $A = kt^2l$.

Display of calculation and reasoning

- (a) (ii) Almost all candidates were able to calculate l correctly.
- (f) (i) The great majority of candidates were able to calculate k for the two sets of data, showing their working clearly. A few candidates calculated t^2/A (i.e. $1/k$) so were not awarded credit.
- (ii) Candidates found it difficult to justify the number of significant figures they had given for the values of k correctly by linking, explicitly, the significant figures for k to the raw data, i.e. d , n , t and A . Reference to just “the raw data” is not sufficient.

Analysis, conclusions and evaluation

- (f) (iii) Most candidates calculated the percentage difference between their two values of k , and then tested it against a specified percentage uncertainty, either taken from (d) or estimated themselves. Some candidates gave answers such as “the difference in the two k values is very large/quite small” which is insufficient. A numerical comparison is required.

Estimating uncertainties

- (d) Most candidates were familiar with the equation for calculating percentage uncertainty, though many made too small an estimate of the absolute uncertainty in the value of A . A common error was to state the uncertainty as simply the smallest scale division on the metre rule (0.1 cm). Candidates should remember that the absolute uncertainty in the value of A depends not only on the precision of the measuring instrument being used, but also on the nature of the experiment itself. A more reasonable estimate of the overall uncertainty in reading the value of A might be between 0.2 cm and 0.5 cm.

Evaluation

- (g) Many candidates recognised that two sets of data were insufficient to draw a valid conclusion, and went on to suggest repeating the experiment for other masses and hence different values of A and t , then plotting a suitable graph. Many also recognised that there were difficulties in measuring d , though fewer gave details of what the difficulties were, such as parallax error, only measuring the outside diameter of the spring, or the end loop of the spring getting in the way.

Similarly, difficulties in measuring the time for 10 oscillations need to be explained explicitly in order to gain credit. Answers such as “human reaction time” are not credited because the reaction time is small compared to the value of t (0.2 s compared with values of t in the region of 7.0 s) and, to an extent, the error is self-cancelling, in that a candidate is likely to both start and stop the stopwatch with the similar reaction times. More valid is the recognition that it is quite difficult to judge exactly when an oscillation is complete (and hence to stop the stopclock).

Many candidates suggested the use of ‘better’ equipment such as motion or distance sensors. These answers can gain credit provided it is also stated how such equipment would be used (for example, by placing the motion/distance sensor below the hanging mass).

Using some kind of (fiducial) marker to indicate the start/finish of oscillations is also a sensible suggestion, but only if the marker is placed at the centre of the oscillation. Markers placed at the extreme points of an oscillation would not work as the amplitude of the oscillations decreases with time. Another improvement would be to use video techniques to record and then replay (slowly) the oscillation, but this on its own is not sufficient. It must also be made clear how the time is to be measured, by, say, using the clock on the video, or by including the stopwatch/stopclock in the recording.

The key to this section is for candidates to identify genuine problems associated with setting up this experiment and in obtaining readings. Candidates are encouraged to suggest detailed practical solutions that either improve technique or give more reliable data. For example, the diameter of the spring could be measured more accurately (and avoiding parallax) using vernier calipers, which could also be used to measure the inside diameter as well as the outside diameter, and then an average value for d calculated.

Credit is not given for suggestions that should be carried out anyway, such as repeating measurements or avoiding parallax errors by looking at an instrument at eye level. Vague or generic answers such as “systematic error”, “parallax error” or “use an assistant” do not gain credit.

PHYSICS

Paper 9702/33
Advanced Practical Skills 1

Key messages

- When preparing the graphical work in **Question 1**, candidates should choose scales for their axes to enable ease of use. This helps in the plotting of points and reading off of coordinates for the gradient and intercept values.
- In the graphical work in **Question 1**, candidates should be encouraged to use a sharp pencil and a transparent 30 cm ruler in order to plot points and draw an appropriate line of best fit. When judging where to place the line of best fit, they should consider the balance of all the points about the line along the entire length. Candidates should be dissuaded from joining the first and last points without considering the balance of the rest of the points, and should also be advised not to force a line through the origin regardless of the position of the points.
- When estimating uncertainties, candidates need to consider the limitations of the experiment and not just the smallest possible reading of the measuring instrument.
- To score highly on **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. General points such as “avoid parallax error” or “use more precise measuring instruments” will not usually gain credit without further detail.

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 a 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. Most candidates were confident in the generation and handling of data but could improve by giving more thought to the critical evaluation of experiments.

Comments on specific questions

Question 1

In this question, candidates were required to investigate how the current in a circuit varies as the resistance of the circuit is changed.

Successful collection of data

- (a) Most candidates measured a value of L with a unit and in range. Many of those who did not gain credit stated 100 without a unit.
- (d)(ii) Some candidates stated a value of I with an appropriate unit and in range. The most common error was a power-of-ten error confusing mA with A. Candidates need to think whether their

answer is realistic or not (100 mA or 100 A). A few candidates omitted units, and were not awarded credit.

- (e) Many candidates were able to set up the experiment and collect six sets of values for x and I so that as x increases, I increases. Some candidates connected the circuit incorrectly or misread the ruler so that as x increases, I decreases giving an incorrect trend.

Range and distribution of values

- (e) Many candidates did not extend the range of readings of x over at least 70.0 cm. The most common ranges were 20.0 – 70.0 cm or 30.0 – 80.0 cm. Candidates should look at the range available to them and spread their readings to make full use of this range.

Presentation of data and observations

Table

- (e) Some candidates were able to include correct units with the column headings. Many candidates stated incorrect units for the $x^2/(x+L)$ or $1/I$ column heading (e.g. cm^2/cm or $\text{cm}^2/2 \text{ cm}$ instead of cm , and A or A^- instead of A^{-1}). Some omitted a unit or the separating mark between the heading and unit. A minority of candidates stated “(x) cm” and this did not gain credit.

Some candidates correctly stated the raw values of x to the nearest mm; many others needed to take account of the precision of the metre rule, as they recorded answers to the nearest cm or added an extra zero and stated x values to the nearest tenth of a mm. Typically those candidates stating length in m often excluded the zero in the mm and cm place (i.e. 0.3 m instead of 0.300 m).

Most candidates were able to calculate $x^2/(x+L)$ correctly and to an appropriate number of significant figures. A few candidates who stated, for example, $x = 50$ then stated the calculated quantity $x^2/(x+L)$ to more than 3 significant figures (e.g. 16.666) incorrectly. Many of the errors in the calculations were due to incorrect rounding.

Graph

- (f) (i) Candidates were required to plot a graph of $1/I$ against $x^2/(x+L)$ and gained credit for drawing appropriate axes with labels and sensible scales. Many candidates chose awkward scales that were either linear (going up in threes or sixes) or non-linear showing gaps in the scale (missing out a number) resulting in errors in read-offs. Candidates can improve the suitability of their graphs 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. Candidates should also check that they have labelled their axes and drawn the correct axes (e.g. I drawn instead of $1/I$). Candidates gained credit for plotting the tabulated readings to within half a small square. A few candidates drew their points as very small dots that could not be seen with the naked eye. These could not gain credit.
- (ii) Some candidates were able to draw a good line of best fit through six points. Other candidates gained credit for drawing a line through five trend points with one clear anomalous point not identified. If a point is being treated as anomalous for the purposes of drawing the line of best fit, this should be indicated clearly on the graph (although it is recommended that any anomalous point first be checked by repeating the measurement using the apparatus). Only one point, if any, should be identified as anomalous and certainly not two or three. Some candidates need to rotate lines to give a better fit or move the line sideways to give a better balance of points along the entire length of the line.

Analysis, conclusions and evaluation

Interpretation of graph

- (f) (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). Many triangles used were too small.

Some candidates showed a correct calculation from their read-offs but then ignored the negative sign when in fact the gradient should be negative. Some candidates read off the y -intercept at $x = 0$ directly from the graph, gaining credit. Others needed to check that the x -axis did actually start at $x = 0$ (i.e. no false origin) in order to validate this method. 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 a point from the table.

Drawing conclusions

- (g) Most candidates recognised that P was equal to the negative value of the gradient and Q was equal to the value of the intercept calculated in (f)(iii), and provided consistent units to gain full credit for this section. Some candidates mixed up the units with a quantity (e.g. $I^{-1} \text{ cm}^{-1}$). 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 method as the question specifically asks for the answers in (f)(iii) to be used.

Question 2

In this question, candidates were required to investigate how the motion of a sphere on a track depends on the radius of the track.

Successful collection of data

- (b)(i) Most candidates recorded a value of y with consistent units and in range. Some candidates did not gain credit as they omitted the units.
- (b)(iii) Many candidates recorded a value of x to the nearest mm and stated a consistent unit. Some candidates stated x either to the nearest tenth of a mm or to the nearest cm, and did not gain credit. Others omitted the unit.
- (c)(iii) Most candidates recorded T with a unit and in range, and also stated evidence of repeat values gaining full credit. Some candidates forgot to divide their time recorded by the number of complete cycles undertaken so their final answer was too large. Some other candidates timed half a complete cycle instead or misread the stop watch (e.g. 0.02 s instead of 2 s) stating a final value that was too small.
- (d) Most candidates recorded a second value for R and T .

Quality

- (d) Most candidates found that, the larger the radius of the track, the larger the value of the time for the complete cycle, gaining credit.

Presentation of data and observations

Display of calculation and reasoning

- (b)(iv) Most candidates were able to calculate R correctly.
- (e)(i) Most candidates were able to calculate $k = T^2/R$ correctly for both experiments. Some candidates rounded their answers to one significant figure so that both k values were identical, and this was not awarded credit. A few candidates calculated T^2R instead, and this was not credited.
- (e)(ii) Few candidates were able to relate the number of significant figures in k to the significant figures used in x and y and T . Common mistakes were to relate to just one quantity, to the "raw data" without specifying the quantities, or to the quantity T^2 or R . Other candidates referred to "the quantity with the least number of significant figures" without stating the actual quantities involved. A few candidates stated a bald "3 s.f." without any reasoning.

Analysis, conclusions and evaluation

- (e) (iii) The quality of responses to this question has improved this year. Strong candidates compared the percentage difference in their values of k by testing it against a specified percentage uncertainty, either taken from (b)(ii) or estimated themselves. Candidates should be encouraged to state what they think is a sensible limit for the percentage uncertainty for this particular experiment. Some candidates gave answers such as “the difference in the two k values is large/small” which were insufficient to gain credit.

Estimating uncertainties

- (b) (ii) Most candidates were familiar with the equation for calculating percentage uncertainty, though few made a realistic estimate of the absolute uncertainty (2 – 5 mm). Many candidates stated the uncertainty as 1 mm, the smallest reading on the ruler (or 0.5 mm, half the smallest reading on the ruler). Candidates should be reminded that the absolute uncertainty in the value of y 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 y is difficult to judge as there is no upper reference point and the bottom of the track is obscured by the track wall. Repeat measurements in y should be encouraged owing to the uncertainty in this measurement. In the case of repeat readings the absolute uncertainty can be calculated as half the range of the results. This method was used by some candidates, though a few of these candidates forgot to halve the range.

Evaluation

- (f) Many candidates scored at least half of the available marks in this section, and the quality of answers has improved. Most candidates were able to state that two readings were not enough to draw a conclusion and so more were needed and a graph should be plotted. Candidates often stated that the measurement of y was difficult to take with appropriate reasons provided and that it was difficult to release the ball without exerting a force. 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 y ” is insufficient to gain credit without saying why it was difficult, e.g. “no reference point at the top to judge the end of y ”.

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 actual difficulties encountered during the experiment, e.g. “difficult to judge y because there is no top reference point”. They can improve their answers by stating the methods used for each solution, e.g. “tie string between the top of the clamps to provide a reference point”. In doing this, candidates should look at how each solution helps and improves this particular experiment. Credit is not given for insufficient detail in procedures such as “use a video” (without the need for a timer) or “use electromagnet to release ball” (without referring to a ball being made out of a magnetic material). Credit is not usually given for suggesting changing the equipment which is under investigation, e.g. changing the track for a different one.

Credit is not given for suggestions that should be carried out anyway. Such suggestions include repeating measurements and calculating averages. General statements such as “parallax error”, “reaction time error”, “use an assistant”, “scales not easy to read”, “materials damaged” or “errors in calculation” do not gain credit.

PHYSICS

Paper 9702/34
Advanced Practical Skills 2

Key messages

- When preparing the graphical work in **Question 1**, candidates should choose scales for their axes to enable ease of use. This helps in the plotting of points and reading off of coordinates for the gradient and intercept values.
- When estimating uncertainties, candidates need to consider the limitations of the experiment and not just the smallest possible reading of the measuring instrument.
- To score highly on **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. General points such as “avoid parallax error” or “use more precise measuring instruments” will not usually gain credit without further detail.
- As a general rule, all transient (i.e. non-static) measurements should be repeated two or three times and an average value calculated; likewise measurements which are likely to vary in different places should be repeated. Such measurements could include, for example, the time for an object to fall, or the temperature of an object at a particular time, or the diameter of a roughly-formed sphere of Plasticine. Static measurements, such as the height of a stationary object, or the reading on an ammeter in a circuit, generally do not require repeat readings.

General comments

Centres reported few problems with providing the necessary apparatus for the two questions. Where apparatus had to be varied slightly and this was recorded in the Supervisor’s Report, the Examiners were able to take this into account.

The majority of candidates had time to complete both questions. In many cases Centres had prepared their candidates well after referring to mark schemes from previous papers. These candidates were familiar with the measuring equipment and knew what was expected in the presentation and analysis of graphs. Candidates from some other Centres had problems using vernier calipers and stopclocks.

If a candidate goes back in an experiment and alters an answer, they must ensure that the alteration is clear with the original value crossed out and the new value written above it. Trying to write on top of the original answer is usually confusing and can result in lost credit if the Examiner is unable to read the work. If the quantity has been used in a subsequent calculation, this must also be amended so that it uses the new value.

The standard shown in calculations was very good, and usually included accurate rounding of answers.

Comments on specific questions

Question 1

In this question, candidates were required to investigate the torsional oscillations of a suspended mass.

Successful collection of data

(a) (i) Most answers showed a value for θ in the expected range. The unit was sometimes omitted.

- (b)(ii)** Most candidates recorded a value for the time t , though in many cases it was below the expected range (these candidates had recorded the time for one swing rather than five swings, perhaps having misread the question). About half of the candidates recorded repeated measurements – an important part of timing oscillations.
- (c)** Nearly every candidate recorded results for five or more different values of θ , and in most cases each increase in θ resulted in the expected increase in t .

Range and distribution of values

- (c)** The apparatus allowed for θ to both increase and decrease from the starting value of 90° , and the best candidates used widely-spaced values in both directions.

Table

- (c)** Tables were generally neat and well-organised. In good answers the headings included units separated from their quantity by using a solidus or by using brackets, e.g. θ° or $\theta(^{\circ})$. A few candidates incorrectly gave a unit of angle for the ratio $\sin^2(\theta/2)$.

Most candidates correctly recorded all their values of t to the nearest 0.1 s or 0.01 s, although some misread their digital stopclock and gave values such as 00.1572 s.

Calculations were nearly always done well. In a small number of cases, too few significant figures were given for a calculated value of t^2 (i.e. less than the number of s.f. used for t itself).

Graph

- (d)(i)** Good graphs had simple, clearly labelled scales with all points from the table clearly and accurately plotted.

There were several graphs where points were plotted as dots that were too big (over 1 mm in diameter) so that the accuracy of plotting could not be checked.

There were many cases of awkward scales. Some candidates chose their lowest coordinates as the origin, giving awkward labels for the major divisions (e.g. 0.413, 0.513, 0.613 etc.). Others chose major divisions that made it difficult to find intermediate values (e.g. 0.15, 0.30, 0.45 etc.). Although this may make the points fill more of the graph grid, it makes plotting and reading more difficult and mistakes more likely, and will not gain the credit available for the choice of scale. Candidates might bear in mind the idea that a scale is “awkward” if a calculator has to be used to determine a coordinate.

In this experiment, careful readings should produce points close to a straight line, so the quality of results was judged by scatter on the graph. In many cases it was good.

- (ii)** Drawn lines were usually clearly defined, and some candidates sensibly circled an outlying point to show that they were ignoring it when choosing their line. Weaker candidates tended to join the first and last points rather than position their line as closely as possible to all points to indicate the overall trend.

Interpretation of graph

- (d)(iii)** Most Centres had prepared candidates well. In good answers, a triangle indicated the coordinates used to calculate the gradient. In a few cases credit was lost because the triangle was too small.

For this experiment the y -intercept could not always be read directly from the t^2 axis (if the x -axis scale did not start from zero). If this was the case the y -intercept value had to be calculated. Most candidates did this successfully, but some could not be credited because they did not show their working.

Drawing conclusions

- (d) The majority of candidates identified the values of the constants q and p as their gradient and intercept values, including any negative sign.

The best candidates used the equation to determine that the unit for both q and p was s^2 .

Question 2

In this question, candidates were required to investigate the effect of a collision between two spheres.

Successful collection of data

- (a) Candidates were required to find the average radius of the spheres, and many had difficulty with this for a number of reasons. Although stronger candidates used the correct method (measuring the diameter and then dividing their average value by two to get the radius), some attempted to measure the radius directly and others did not divide the diameter by two. Errors in interpreting the reading from the vernier calipers were also frequently seen.
- (b) Candidates were required to measure the dimensions e and l between positions marked on their board. They were provided with a metre rule and a 30 cm ruler so their initial readings were in cm, and these had to be converted to mm before recording on the answer lines. A large proportion of candidates found this difficult, giving for example 6.3 cm as 0.63 mm or even 0.063 mm. It is very important that candidates have practice in converting between the various prefixes, and they should also be able to estimate a measurement. It is worth encouraging candidates to ask themselves “how big is this distance?” and “is my value sensible?”
- (c) (ii) Most candidates recorded a value for x , the deviation of the second sphere after the collision. This quantity is of the type where taking the average of repeated readings is a sensible choice. Although it is likely that most candidates repeated the collision, only about half recorded their repeated measurements of x . All raw data should be recorded to give an indication of scatter.
- (d) Most candidates repeated the experiment using the ramp position B.

Estimating uncertainties

- (c) (iii) In this experiment, there is considerable scatter in the value of x when the collision is repeated, and also the measurement is subject to uncertainty in the location of the centre of the sphere and to parallax error in the measurement itself. All of these lead to an uncertainty greater than the 1 mm precision of the ruler. Only very strong candidates recognised this and chose an absolute uncertainty of 2 mm or more to use in their calculation of percentage uncertainty. The best candidates looked at the range and used half of this in their calculation.

Display of calculation and reasoning

- (c) (iv) The calculation of the deviation angle θ was done well, with very few candidates choosing too many significant figures or making a rounding error when recording the result.
- (e) (i) Most candidates successfully calculated two values for the constant k . Only a few made mistakes when rearranging the equation or when transferring values into their formula.

Drawing conclusions

- (e) (ii) For the suggested relationship to be true, k must be constant. Candidates who were well prepared produced a clearly-reasoned conclusion based on their two k values. They looked at the relative difference between the two values (i.e. the percentage difference) and looked at whether it fell within a (stated) percentage variation that they felt was reasonable for this experiment. The best candidates used the percentage uncertainty from (c)(iii) as their acceptable variation. Weaker answers only discussed whether the difference between k values was ‘large’ or ‘small’ and this was not credited.

Evaluation

- (f) Many candidates correctly identified and described problems presented by this experiment, gaining credit for identifying problems with positioning the ramp and with measuring x (locating the centre of the sphere, and parallax error). Weaker candidates mentioned parallax error but not x , which is the measurement affected. Stronger candidates could suggest techniques to overcome these problems, but many answers lacked sufficient detail or were impractical (e.g. “mark the centre of the sphere”). Sometimes a small diagram could have made an explanation clearer.

The other major problem was getting the spheres to stick to the tape. Strong candidates described it clearly, but many just said the tape was “not sticky enough” without mentioning the problem this caused. Although the idea of “making the tape stickier” was often suggested, answers nearly always lacked the detail of how this would be done. The best answers discussed other ways of leaving a marker where the contact had occurred, or suggested using video with a measuring scale in the picture.

There were some problems that many candidates offered but were not credited. “The scale did not start at zero when measuring l ” suggested that the candidate was using the ruler rather than the metre rule. The impact velocity would have little effect on the direction after the collision, so “difficult to start the sphere from the same position on the ramp” and “difficult to release without applying a force” were not relevant.

PHYSICS

<p>Paper 9702/35 Advanced Practical Skills 1</p>
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Key messages

- When preparing the graphical work in **Question 1**, candidates should choose scales for their axes to enable ease of use. This helps in the plotting of points and reading off of coordinates for the gradient and intercept values.
- In the graphical work in **Question 1**, candidates should be encouraged to use a sharp pencil and a transparent 30 cm ruler in order to plot points and draw an appropriate line of best fit. When judging where to place the line of best fit, they should consider the balance of all the points about the line along the entire length. Candidates should be dissuaded from joining the first and last points without considering the balance of the rest of the points, and should also be advised not to force a line through the origin regardless of the position of the points.
- When estimating uncertainties, candidates need to consider the limitations of the experiment and not just the smallest possible reading of the measuring instrument.
- To score highly on **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. General points such as “avoid parallax error” or “use more precise measuring instruments” will not usually gain credit without further detail.

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 a 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.

Some Centres detailed any problems encountered with the loads requested in **Question 2** and sensibly made adjustments necessary for the candidates to obtain a set of data using the apparatus. Whilst most Supervisors coped with this well, a few Supervisors made ‘improvements’ which affected the candidates’ ability to access fully the evaluation section of the question.

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

Comments on specific questions

Question 1

In this question, candidates were required to investigate a lever system in equilibrium.

Successful collection of data

- (b)(iii) Most candidates measured a value of a in range, with a unit and larger than b . Those who were not awarded credit had often omitted the unit.
- (b)(iv) Some candidates stated a value of L with an appropriate unit and in range. The most common error was a power-of-ten error confusing cm with m or mm. Candidates should be encouraged to think whether their answer is realistic or not (10.0 m or 10.0 cm). A few candidates omitted units and could not gain credit.
- (d) Many candidates were able to set up the experiment and collect six sets of values for a and b with the right trend (as a increases, b increases). Some candidates set up the apparatus incorrectly or misread the ruler giving rise to an incorrect trend.

Range and distribution of values

- (d) Many candidates did not extend the range of readings of a over at least 39 cm. Candidates should look at the range available to them and spread out the readings to make full use of this range.

Presentation of data and observations

Table

- (d) Many candidates were able to include correct units with the column headings. Some candidates stated incorrect units for the a/b or $1/b$ column heading (e.g. cm/cm instead of no units for the former and cm instead of cm^{-1} for the latter), or omitted a separating mark between the quantity and unit. A minority of candidates stated “(a) cm” which is not scientific convention and so were not given credit.

Some candidates correctly stated the raw values of a and b to the nearest mm; many others needed to take account of the precision of the metre rule, as they recorded answers to the nearest cm or added an extra zero and stated a and b values to the nearest tenth of a mm. Typically those candidates stating length in m often excluded the zero in the mm and cm place (i.e. 0.39 m instead of 0.390 m).

Most candidates were able to calculate a/b correctly and state $1/b$ to an appropriate number of significant figures. Many of the errors in the calculation of a/b were due to incorrect rounding.

Graph

- (e)(i) Candidates were required to plot a graph of $1/b$ against a/b and gained credit for drawing appropriate axes with labels and sensible scales. Many candidates chose awkward scales that were either linear (going up in threes or sixes) or non-linear showing gaps in the scale (missing out a number) resulting in errors in read-offs. Candidates can improve the suitability of their graphs 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. Candidates should also check that they have labelled their axes and drawn the correct axes (e.g. b drawn instead of $1/b$). Candidates gained credit for plotting the tabulated readings to within half a small square. A few candidates drew their points so that they were very small dots that could not be seen with the naked eye. These could not gain credit.
- (e)(ii) Some candidates were able to draw a good line of best fit through six points. Other candidates gained credit for drawing a line through five trend points with one clear anomalous point not identified. If a point is being treated as anomalous for the purposes of drawing the line of best fit, this should be indicated clearly on the graph (although it is recommended that any anomalous point first be checked by repeating the measurement using the apparatus). Only one point, if any, should be identified as anomalous and certainly not two or three. Some candidates need to rotate lines to give a better fit or move the line sideways to give a better balance of points along the entire length of the line.

Analysis, conclusions and evaluation

Interpretation of graph

- (f) (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). Many triangles used were too small.

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 showed a correct calculation from their read-offs and then ignored the negative sign when in fact the gradient should be negative. Some candidates read off the y -intercept at $x = 0$ directly from the graph, gaining credit. Others needed to check that the x -axis did actually start at $x = 0$ (i.e. no false origin) in order to validate this method. 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 a point from the table.

Drawing conclusions

- (f) Most candidates recognised that P was equal to the negative value of the gradient and Q was equal to the value of the intercept calculated in (e)(iii), and gained full credit for this section. Other candidates 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 method as the question specifically asks for the answers in (e)(iii) to be used.
- (g) Many candidates succeeding in calculating a value of M in range. Candidates who were not awarded credit often had a power-of-ten error in their length measurements or gave incorrect units.

Question 2

In this question, candidates were required to investigate how the extension of a Plasticine cylinder under an applied load depends on the diameter of the cylinder.

Successful collection of data

- (a) (ii) Many candidates recorded repeat values of d with consistent units, to the nearest 0.01 mm and in the required range to gain full credit for this section. Some candidates who did not gain credit either did not repeat their readings or stated the d value to the nearest mm or 0.1 mm. Where Supervisors had made adjustments to the apparatus to enable it to function satisfactorily, candidates' values were compared with the Supervisor's value.
- (c) (iv) Many candidates recorded a value of x_1 to the nearest mm and stated a consistent unit. Some candidates stated x_1 either to the nearest tenth of a mm or to the nearest cm, and did not gain credit. Others omitted the unit.
- (d) (ii) All candidates recorded a second value for d and x_1 .

Quality

- (d) (ii) Most candidates gained credit by finding that, for the larger diameter of Plasticine, the extension under load was smaller.

Presentation of data and observations

Display of calculation and reasoning

- (c) (v) All candidates were able to calculate e correctly.

- (e) (i) Most candidates were able to calculate $k = ed^4$ correctly for both experiments. Some candidates rounded their answers to one significant figure so that both k values were identical, and this was not awarded credit. A few candidates calculated ed^2 or e/d^4 instead, and this was not credited.
- (e) (ii) Some candidates were able to relate the number of significant figures in k to the number of significant figures used in e or $(x_1 - x)$ and d . Common mistakes were to relate to just one quantity or to the “raw data” without specifying the quantities used. Other candidates referred to “the quantity with the least number of significant figures” without stating the actual quantities involved. A few candidates stated a bald “3 s.f.” without any reasoning.

Analysis, conclusions and evaluation

- (e) (iii) The quality in responses in the question has improved this year. 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. Some candidates gave answers such as “the difference in the two k values is large/ small” which were insufficient to gain credit.

Estimating uncertainties

- (a) (iii) Most candidates were familiar with the equation for calculating percentage uncertainty, though few made a realistic estimate of the absolute uncertainty (0.05 – 2.00 mm). Some candidates stated the uncertainty as 0.01 mm, the smallest reading on the micrometer (or 0.005 mm, half the smallest reading). Candidates should be reminded that the absolute uncertainty in the value of d 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 d is difficult to judge as the ‘jaws’ of the micrometer can easily dig into the Plasticine if wound too far, and it is hard to obtain a perfect cylinder. Repeat measurements of d should be encouraged owing to the uncertainty in this measurement. In the case of repeat readings the absolute uncertainty can be calculated as half the range of the results. This method was used by some candidates, though a few of these candidates forgot to halve the range.

Evaluation

- (f) Many candidates scored at least half of the available marks in this section and the quality of answers has improved. Most candidates were able to state that two readings were not enough to draw a conclusion and so more were needed and a graph should be plotted. Candidates often stated that the Plasticine was difficult to roll to get an even diameter throughout. Some candidates stated that it was difficult to load the Plasticine without it breaking or, if it did break, that the break became the source for further weaknesses. There were some good problems identified that were specific to the experiment and this enabled candidates to score highly. Candidates should be encouraged to add detail to their answers. An answer such as “it is difficult to measure x_1 ” is insufficient to gain credit without saying why it was difficult, e.g. “the marks in the Plasticine widened”.

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 actual difficulties encountered during the experiment, e.g. “difficult to measure d accurately as the micrometer digs into the Plasticine”. They can improve their answers by stating the methods used for each solution. In doing this candidates should look at how each solution helps and improves this particular experiment. Credit is not given for insufficient detail in procedures, e.g. “broke too easily”. Credit is also not usually given for suggestions that should be carried out anyway, such as repeating measurements and calculating averages.

General statements such as “parallax error”, “reaction time error”, “use an assistant”, “scales not easy to read”, “materials damaged” or “errors in calculation” do not gain credit.

PHYSICS

Paper 9702/41
A2 Structured Questions

Key messages

- Physics is a precise science and, as such, candidates should take care as to what they write. Often, credit is lost through using everyday language. For instance, there is a clear distinction between 'work done' and 'energy' and yet these two terms are frequently used indiscriminately.
- Questions that state 'explain your working' or 'show that' can rarely be awarded full credit if there is no explanation given. Candidates should be encouraged to think whether their answer provides a complete explanation. A question stating 'explain quantitatively' requires numerical work as well as some accompanying words of explanation.
- Candidates should be reminded that the use of labels is essential when drawing diagrams. It is not usually possible to award credit to unlabelled diagrams, because without labels it is not clear what is intended in the diagram. Many candidates could be awarded more credit for diagrams if these were given clear labels.
- It is worthwhile for candidates to take a moment to think whether any numerical answer they give is reasonable. If it is unreasonable, this could indicate a mistake with arithmetic or with a power-of-ten.

General comments

This paper provided candidates of all abilities with an opportunity to show their knowledge and understanding of a wide variety of topics. Well-prepared candidates were able to score highly in **Section B**.

Candidates should ensure that they learn carefully the key definitions in the syllabus. They should also always ensure that numerical answers are given with an appropriate number of significant figures, as this is a common cause of lost credit.

There was no evidence that adequately prepared candidates were short of time.

Comments on specific questions

Section A

Question 1

- (a) In the vast majority of cases a correct definition of gravitational potential was given. It is essential that candidates refer to unit mass.
- (b) The symbol ϕ was defined in the question as being the magnitude of the gravitational potential. Since gravitational potential energy is always negative, the correct relation must include a negative sign.
- (c) Candidates were usually able to state the appropriate equations, but often lacked the depth of understanding of the underlying physics that was needed to apply them correctly. A common error was to use the mass of the stone as the mass of the planet.

Question 2

- (a) The Avogadro constant is the number of atoms in 12 g of carbon-12. It was insufficient to merely quote a numerical value of the Avogadro constant or to refer to particles instead of atoms.
- (b) Parts (i) and (ii) were generally well answered, although it was common to see power-of-ten errors in the mass and the volume of the gas. A small minority of candidates did not appreciate the need to convert the temperature from °C to K. In (iii), candidates were often able to state a correct equation, but needed to have a greater understanding of the underlying physics in order to apply it correctly. The most common mistake was to confuse the total mass of the gas with the mass of a single atom. Some candidates calculated the mean-square speed, but then forgot to take the square root to obtain the r.m.s. speed.

Question 3

- (a) The calculation needed to show the volume of the liquid being subtracted from the volume of the vapour.
- (b)(i) This was answered correctly by most candidates.
- (ii) A significant proportion of candidates showed that they did not understand the difference between the work done on or by a system. For these candidates, the value of the work done by the water was expressed with the wrong sign.

Question 4

- (a) The vast majority of answers correctly identified that kinetic energy was represented in the graph.
- (b) Most candidates found this part of the question challenging. Correct calculations were usually based on the maximum kinetic energy being proportional to the square of the amplitude. A few candidates realised that the change in the maximum kinetic energy was 0.60 mJ and then used this value to read the new amplitude directly from the graph. A significant number of candidates wrongly stated the new amplitude, rather than the change in amplitude, as their final answer. These candidates would have benefited from more careful reading of the question.

Question 5

The standard of the graphs varied widely. Many candidates drew nothing from $x = 0$ to $x = r$, even though the question explicitly asked them to do so. The decrease in the field strength and in the potential outside of the sphere was reasonably well understood. Candidates were required to draw precise curves. Scales were given on both axes and so the curves needed to be drawn carefully through the appropriate points.

Question 6

- (a)(i) There were many incorrect calculations that were based on an expression for the energy stored in a capacitor. The simplest approach is simply to use the e.m.f. of the battery and the charge, without any reference to the capacitor.
- (ii) The potential difference across the capacitor was usually calculated correctly. The calculation of the energy stored in the capacitor was also done well, although some of the weaker candidates made power-of-ten errors or expressed their final answer to only one significant figure.
- (b) It was expected that candidates would explain that thermal energy is lost in the wires or resistor. Many candidates merely stated that 'energy is lost' and this did not provide enough detail to be credited.

Question 7

- (a) The graph needed to show the voltage increasing sharply from zero when the current is switched on, followed by a section with the voltage remaining constant and then the voltage finally decreasing back to zero when the current is switched off. A common error was to show the voltage decreasing before the current is switched off. A significant proportion of candidates appeared simply to guess a graph shape such as a sine curve. It is important that candidates are given opportunities to perform practical work using Hall probes in order to enhance their understanding of the underlying physics that will be assessed in this type of question.

- (b)(i) The vast majority of candidates were able to accurately recall Faraday's law of electromagnetic induction.
- (ii) Only a small minority of candidates were able to apply Faraday's law to the situation in this question. Few appreciated that a short 'pulse' of e.m.f. would be induced in the coil when the current is switched on and also when it is switched off. Even fewer were able to reason that the e.m.f. of these two pulses would be in opposite directions.

Question 8

- (a) A precise statement of what is meant by quantisation of charge needed to be given. Few candidates stated that charge exists in discrete and equal amounts. An alternative way of stating this is to say that charge exists as integral multiples of the elementary charge.
- (b) This part of the question was done very well in general.
- (c) When candidates are explicitly asked to explain their working, it is vital that they do so. For the award of credit, candidates needed to explain why the elementary charge is 1.6×10^{-19} C. Many gained partial credit for explaining that all the charges are approximate multiples of 1.6×10^{-19} C. However, these charges are also approximate multiples of other values, for example 0.8×10^{-19} C. Therefore, the full explanation is that the elementary charge is the highest common factor of all the different values of charge. A common error was to calculate the elementary charge as being the average of the four charges.

Question 9

- (a) The most commonly stated correct observation was that there is no time delay between the illumination of the metal and the emission of electrons. All observations needed to be stated precisely. For example, it is not enough to say that "kinetic energy depends on frequency" when the precise statement is that "the maximum kinetic energy of the emitted electrons depends on the frequency". A common mistake was to give some factual information about the photoelectric effect that was not a direct observation.
- (b)(i) Only a small proportion of the candidates appreciated that a photon may interact with an electron below the metal surface so that energy is then required to bring the electron up to the surface.
- (ii) 1. The threshold frequency could be determined by extrapolating the graph line to find its intercept with the x-axis. A common misconception was that the threshold frequency corresponds to the lowest point on the graph line shown, before it is extrapolated.
2. The easiest way of calculating the work function energy was simply to multiply the threshold frequency by the Planck constant. Many candidates performed an alternative calculation that involved substituting the values from a single point on the graph line into the photoelectric equation. Some candidates did not appear to have read the question carefully and expressed the final answer in J rather than in the required eV.

Question 10

- (a) Explanations of what is meant by the binding energy of a nucleus were usually satisfactory. Weaker candidates sometimes confused nucleons with nuclei.
- (b) The calculations proved to be straightforward for well-prepared candidates. Weaker candidates were usually able to calculate the mass defect, but then made errors when trying to convert the mass defect into the binding energy. Care must be taken when writing down values of mass that have many decimal places so that transcription errors are avoided.
- (c) Candidates found this part of the question challenging, with many unable to explain that the total binding energy of the barium and krypton is greater than the binding energy of uranium.

Section B

Question 11

- (a) (i) It should be noted that the circuit is called an ‘inverting amplifier’ and not an ‘inverting operational amplifier’.
- (ii) The standard of the explanation was often Centre-specific, with some Centres preparing their candidates much better than others. Stronger candidates were able to explain that the potential at the non-inverting input is zero and therefore, in order for the amplifier not to saturate, the potential at P must be almost zero. However, many of these candidates did not explain that saturation would otherwise occur because an ideal operational amplifier has infinite gain.
- (b) (i) The majority of the candidates found these calculations difficult, even though they were based on simple gain equations. The values of the resistances needed to be entered into the table with the correct unit and care was needed to avoid making power-of-ten errors.
- (ii) Very few candidates realised that the circuit could be used as a variable range meter.

Question 12

- (a) The standard of the explanations was variable. Candidates who had prepared diligently were able to give clear and succinct explanations that often gained full credit. However, there were also many poor responses that either presented the information in a disordered way or else missed out key steps. Weaker candidates often thought that the X-ray images that were taken from many angles were then immediately used to build up a 3D image of the whole object, rather than an image of one thin section through the object. In order to build up an image of the whole object, the procedure must first be repeated for many different sections. The images of these sections are then finally used to build up the 3D image.
- (b) The pixel numbers were usually calculated correctly, although some candidates either divided the detector readings by 3 without first subtracting the background reading or merely subtracted the background reading.

Question 13

- (a) Most candidates could state at least one correct advantage of digital transmission. A common misconception was that digital signals do not pick up noise. Digital signals do pick up noise, but have the advantage that this noise can be eliminated in the process of regenerating the original signal. Another common misconception was the digital signals are less attenuated.
- (b) The parallel-to-serial converter receives a number of bits all at one time and then sends these bits one after another. It is not sufficient for candidates to say that it “receives bits in parallel and sends bits in series” as this merely paraphrases the question.
- (c) The key to answering this part of the question was to know that the sampling needs to occur at a frequency that is at least twice the highest frequency component in the original signal. Partial credit was available for an appropriate comment relating to the quality of reproduction of sound.

Question 14

- (a) Most candidates could accurately recall what is meant by the attenuation of a signal.
- (b) (i) The vast majority of answers were correct.
- (ii) Most candidates had clearly practised this type of calculation, although a small number applied the appropriate expression for attenuation but with the power ratio inverted.
- (c) There were many correct answers, although a common mistake was to simply compare decibels with bels.

PHYSICS

Paper 9702/42

A2 Structured Questions

Key messages

- Physics is a precise science and, as such, candidates should take care as to what they write. Often, credit is lost through using everyday language. For instance, there is a clear distinction between 'work done' and 'energy' and yet these two terms are frequently used indiscriminately.
- Questions that state 'explain your working' or 'show that' can rarely be awarded full credit if there is no explanation given. Candidates should be encouraged to think whether their answer provides a complete explanation. A question stating 'explain quantitatively' requires numerical work as well as some accompanying words of explanation.
- Candidates should be reminded that the use of labels is essential when drawing diagrams. It is not usually possible to award credit to unlabelled diagrams, because without labels it is not clear what is intended in the diagram. Many candidates could be awarded more credit for diagrams if these were given clear labels.
- It is worthwhile for candidates to take a moment to think whether any numerical answer they give is reasonable. If it is unreasonable, this could indicate a mistake with arithmetic or with a power-of-ten.

General comments

The paper contained some straightforward questions which required a good memory and an understanding of the syllabus content. It also contained sections of questions where candidates had to apply their knowledge to, perhaps, unfamiliar situations. The result was that there was a wide distribution of marks, with high marks being scored by well-prepared candidates.

There appeared to be adequate time for the great majority of candidates to complete their answers.

Comments on specific questions

Section A

Question 1

- (a) Many candidates did not explain that the gravitational force provides the centripetal force. For many candidates, the starting point was an algebraic equation. These candidates should be reminded that the instruction 'explain your working' indicates that some credit is given for the explanation, and this credit will not be given if there is no explanation.
- (b)(i) Similarly, despite being instructed to give explanation, only a minority stated that the gain in kinetic energy would be equal to the loss in gravitational potential energy. It was expected that the final expression would be given in terms of x , not r .
- (ii) Many candidates did not derive expressions in (a) and (b)(i) that were dimensionally correct and, thus, no comparison could be made. Generally, where the expressions were correct, the correct conclusion was stated, rather than explained.

Question 2

- (a) In most answers, some form of the ideal gas equation was used. Frequently, terms such as n , N and R were omitted. Where a numerical expression was derived for the initial and for the final conditions, many did not write down a conclusion.
- (b)(i) With few exceptions, a correct expression was used. Some candidates made a power-of-ten error in the volume of the gas.
- (ii) Despite being instructed in (b)(i) to calculate the work done *by* the gas, it was common to find that the heating and work done were summed.
- (c) This part was generally well answered. The most common omission was to state that the potential energy of the gas molecules is zero without mention that there are no intermolecular forces. Candidates should appreciate the difference between stating zero potential energy and constant potential energy.

Question 3

- (a) Most candidates were able to answer this question.
- (b) This question was generally answered correctly. There were some difficulties with powers-of-ten.
- (c) Despite the question stating that more detail than 'heat lost to the surroundings' is required, this was a common answer. Appropriate references included evaporation and thermal energy gained by the water container.

Question 4

- (a)(i) Although this was completed successfully by the majority of candidates, errors associated with calculating $2e$ (rather than e^2) and using x (rather than x^2) were common, especially amongst less-able candidates.
- (ii) Similar errors to those made in (i) were made here, usually by the same candidates.
- (b)(i) Very few answers included sufficient detail. Although the magnitudes of the forces were discussed, there was rarely any statement of whether the forces are attractive or repulsive.
- (ii) Very few candidates appeared to have any appreciation of the situation, and there were many references to electrons and neutrons. The fact that the attractive force must act only within the nucleus because, outside, the protons repel each other was mentioned very rarely. There were a few comments to the effect that all matter would stick together if this force were to be long-range.

Question 5

- (a) It was expected that a smooth curve would be drawn, starting at $x = d$ and not reaching the x -axis. Candidates found this difficult and many drew sinusoidal waves. Where a smooth curve was drawn, this frequently either had a finite value at $x = 0$ (i.e. displaced to the left by d relative to the correct curve) or cut the x -axis.
- (b) Most sketches did indicate a sine wave with the correct period. The most common error was to draw the curve with an inappropriate amplitude.
- (c) This was a challenging question. It would appear that a significant number of candidates have not experienced the use of a search coil and were not able to use their knowledge of Faraday's law to predict its behaviour. Of those who did realise that the suggestion is faulty, many merely quoted Faraday's law as it would apply to the coil. They did not go on to give any detail such as why there would not be an induced e.m.f. or how the procedure could be modified to provide readings.

Question 6

- (a) A space was provided for a diagram. Many candidates drew diagrams that were not clear enough to be given credit. It was expected that an electric field would be shown normal to a magnetic field and in the same region. The initial path of the charged particle would be at right-angles to both fields. In practice, the large majority of diagrams indicated approximately parallel plates, marked +

and $-$, and crosses between the plates. Labelling was often either missing or inappropriate. Candidates do need to explain their answers and this was further exemplified by many stating $v = E/B$ without any reference to there being no deviation.

- (b)(i) The majority of answers were correct. The most common errors were either powers-of-ten or substituting an incorrect value for the radius.
- (ii) The question states that the ions are of the same isotope, but many candidates attributed the different radii to different mass rather than to different charge. There were a small number of answers from strong candidates where a complete quantitative analysis of the situation was given.

Question 7

- (a) In most cases the length of arc was said to be equal to the radius. The point at which the angle is subtended was not always made clear.
- (b)(i) Many candidates divided the distance by the angle, thus obtaining a very large distance for the diameter. Candidates should be encouraged to consider whether any answer is reasonable.
- (ii) With few exceptions, it was stated that Mars is further from Earth than the Moon. However, few then linked this fact with a smaller angle subtended at the telescope.

Question 8

- (a) Most candidates calculated the photon energy. There was some confusion as to how to combine this energy with the power of the light in order to obtain the photon flux.
- (b)(i) Many candidates did not appear to know the de Broglie equation. Some answers, which were left without comment, were unrealistic.
- (ii) In the majority of scripts, it was correctly recognised that the total momentum calculated in (b)(i) would be numerically equal to the force.

Question 9

- (a) Candidates found it difficult to state precise definitions. It is expected that reference is made to the time for either the number of atoms/nuclei or the activity to be reduced to half of its initial value. Many answers either did not make a reference to what would decay or merely stated 'the amount halves' which was too vague.
- (b)(i) In general, candidates who appreciated the starting point for this calculation were able to reach a satisfactory conclusion. Others calculated the number of iodine-131 atoms in 1 kg of iodine.
- (ii) The most common error was to have one quantity in moles and the other as a number of molecules.
- (c) This standard calculation was completed successfully by the majority of candidates, including many who could not reach a satisfactory conclusion in (b)(i).

Section B

Question 10

- (a) Most candidates could not clearly express the function of a comparator circuit. Most made reference to voltages and inputs, without making it clear where the potentials are applied and how the output potential depends on these input potentials.
- (b)(i) Correct answers were in a minority. Many candidates drew a ring around only one diode.
- (ii) This part was answered successfully by most candidates.

- (iii) 1. The majority of graphs indicated switching at the correct points, but the direction of switching was frequently incorrect. The most common misunderstanding was to draw the output as a sinusoidal wave.
2. In most cases, the state of the diodes at t_1 and t_2 did match what was drawn in Fig. 10.2.

Question 11

- (a) This question was generally well answered. In many scripts, comment regarding an X-ray image was limited to stating that it is a 2D image without any further detail.
- (b) (i) The majority of answers were correct. Some candidates did not know what expression should be used.
- (ii) In many scripts, the ratio for the aluminium filter alone was calculated. A common error was to add the two ratios, rather than find their product.
- (iii) The great majority of answers had the correct numerical value. Very few retained the negative sign in order to indicate that there is an attenuation.

Question 12

- (a) (i) This question was answered well in most scripts. Candidates should be advised to distinguish clearly between orbital rotation about the Sun and rotation about the axis of the Earth. Stating that the satellite has 'the same period' as the Earth is imprecise because it is not clear which of these periods is intended.
- (ii) Swamping was sometimes confused with interference. For a complete answer, candidates should state that the uplink signal is highly attenuated and that it is the downlink signal that swamps the uplink signal.
- (b) In most answers, it was realised that the geostationary satellite would give rise to a time delay. The reason was not always clear. Very few stated that the speed of the signal would be of the same order of magnitude in both systems. Some candidates attributed the difference in delay to a difference in speed of signal rather than to a difference in distance travelled.

PHYSICS

Paper 9702/43

A2 Structured Questions

Key messages

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- It is worthwhile for candidates to take a moment to think whether any numerical answer they give is reasonable. If it is unreasonable, this could indicate a mistake with arithmetic or with a power-of-ten.

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Candidates should ensure that they learn carefully the key definitions in the syllabus. They should also always ensure that numerical answers are given with an appropriate number of significant figures, as this is a common cause of lost credit.

There was no evidence that adequately prepared candidates were short of time.

Comments on specific questions

Section A

Question 1

- (a) In the vast majority of cases a correct definition of gravitational potential was given. It is essential that candidates refer to unit mass.
- (b) The symbol ϕ was defined in the question as being the magnitude of the gravitational potential. Since gravitational potential energy is always negative, the correct relation must include a negative sign.
- (c) Candidates were usually able to state the appropriate equations, but often lacked the depth of understanding of the underlying physics that was needed to apply them correctly. A common error was to use the mass of the stone as the mass of the planet.

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- (a) The Avogadro constant is the number of atoms in 12 g of carbon-12. It was insufficient to merely quote a numerical value of the Avogadro constant or to refer to particles instead of atoms.
- (b) Parts (i) and (ii) were generally well answered, although it was common to see power-of-ten errors in the mass and the volume of the gas. A small minority of candidates did not appreciate the need to convert the temperature from °C to K. In (iii), candidates were often able to state a correct equation, but needed to have a greater understanding of the underlying physics in order to apply it correctly. The most common mistake was to confuse the total mass of the gas with the mass of a single atom. Some candidates calculated the mean-square speed, but then forgot to take the square root to obtain the r.m.s. speed.

Question 3

- (a) The calculation needed to show the volume of the liquid being subtracted from the volume of the vapour.
- (b)(i) This was answered correctly by most candidates.
- (ii) A significant proportion of candidates showed that they did not understand the difference between the work done on or by a system. For these candidates, the value of the work done by the water was expressed with the wrong sign.

Question 4

- (a) The vast majority of answers correctly identified that kinetic energy was represented in the graph.
- (b) Most candidates found this part of the question challenging. Correct calculations were usually based on the maximum kinetic energy being proportional to the square of the amplitude. A few candidates realised that the change in the maximum kinetic energy was 0.60 mJ and then used this value to read the new amplitude directly from the graph. A significant number of candidates wrongly stated the new amplitude, rather than the change in amplitude, as their final answer. These candidates would have benefited from more careful reading of the question.

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The standard of the graphs varied widely. Many candidates drew nothing from $x = 0$ to $x = r$, even though the question explicitly asked them to do so. The decrease in the field strength and in the potential outside of the sphere was reasonably well understood. Candidates were required to draw precise curves. Scales were given on both axes and so the curves needed to be drawn carefully through the appropriate points.

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- (a)(i) There were many incorrect calculations that were based on an expression for the energy stored in a capacitor. The simplest approach is simply to use the e.m.f. of the battery and the charge, without any reference to the capacitor.
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- (b) (i) The vast majority of candidates were able to accurately recall Faraday's law of electromagnetic induction.
- (ii) Only a small minority of candidates were able to apply Faraday's law to the situation in this question. Few appreciated that a short 'pulse' of e.m.f. would be induced in the coil when the current is switched on and also when it is switched off. Even fewer were able to reason that the e.m.f. of these two pulses would be in opposite directions.

Question 8

- (a) A precise statement of what is meant by quantisation of charge needed to be given. Few candidates stated that charge exists in discrete and equal amounts. An alternative way of stating this is to say that charge exists as integral multiples of the elementary charge.
- (b) This part of the question was done very well in general.
- (c) When candidates are explicitly asked to explain their working, it is vital that they do so. For the award of credit, candidates needed to explain why the elementary charge is 1.6×10^{-19} C. Many gained partial credit for explaining that all the charges are approximate multiples of 1.6×10^{-19} C. However, these charges are also approximate multiples of other values, for example 0.8×10^{-19} C. Therefore, the full explanation is that the elementary charge is the highest common factor of all the different values of charge. A common error was to calculate the elementary charge as being the average of the four charges.

Question 9

- (a) The most commonly stated correct observation was that there is no time delay between the illumination of the metal and the emission of electrons. All observations needed to be stated precisely. For example, it is not enough to say that "kinetic energy depends on frequency" when the precise statement is that "the maximum kinetic energy of the emitted electrons depends on the frequency". A common mistake was to give some factual information about the photoelectric effect that was not a direct observation.
- (b) (i) Only a small proportion of the candidates appreciated that a photon may interact with an electron below the metal surface so that energy is then required to bring the electron up to the surface.
- (ii) 1. The threshold frequency could be determined by extrapolating the graph line to find its intercept with the x-axis. A common misconception was that the threshold frequency corresponds to the lowest point on the graph line shown, before it is extrapolated.
2. The easiest way of calculating the work function energy was simply to multiply the threshold frequency by the Planck constant. Many candidates performed an alternative calculation that involved substituting the values from a single point on the graph line into the photoelectric equation. Some candidates did not appear to have read the question carefully and expressed the final answer in J rather than in the required eV.

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- (c) Candidates found this part of the question challenging, with many unable to explain that the total binding energy of the barium and krypton is greater than the binding energy of uranium.

Section B

Question 11

- (a) (i) It should be noted that the circuit is called an ‘inverting amplifier’ and not an ‘inverting operational amplifier’.
- (ii) The standard of the explanation was often Centre-specific, with some Centres preparing their candidates much better than others. Stronger candidates were able to explain that the potential at the non-inverting input is zero and therefore, in order for the amplifier not to saturate, the potential at P must be almost zero. However, many of these candidates did not explain that saturation would otherwise occur because an ideal operational amplifier has infinite gain.
- (b) (i) The majority of the candidates found these calculations difficult, even though they were based on simple gain equations. The values of the resistances needed to be entered into the table with the correct unit and care was needed to avoid making power-of-ten errors.
- (ii) Very few candidates realised that the circuit could be used as a variable range meter.

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- (a) The standard of the explanations was variable. Candidates who had prepared diligently were able to give clear and succinct explanations that often gained full credit. However, there were also many poor responses that either presented the information in a disordered way or else missed out key steps. Weaker candidates often thought that the X-ray images that were taken from many angles were then immediately used to build up a 3D image of the whole object, rather than an image of one thin section through the object. In order to build up an image of the whole object, the procedure must first be repeated for many different sections. The images of these sections are then finally used to build up the 3D image.
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- (b) The parallel-to-serial converter receives a number of bits all at one time and then sends these bits one after another. It is not sufficient for candidates to say that it “receives bits in parallel and sends bits in series” as this merely paraphrases the question.
- (c) The key to answering this part of the question was to know that the sampling needs to occur at a frequency that is at least twice the highest frequency component in the original signal. Partial credit was available for an appropriate comment relating to the quality of reproduction of sound.

Question 14

- (a) Most candidates could accurately recall what is meant by the attenuation of a signal.
- (b) (i) The vast majority of answers were correct.
- (ii) Most candidates had clearly practised this type of calculation, although a small number applied the appropriate expression for attenuation but with the power ratio inverted.
- (c) There were many correct answers, although a common mistake was to simply compare decibels with bels.

PHYSICS

Paper 9702/51

Planning, Analysis and Evaluation

Key messages

- In **Question 1**, candidates' responses should include detailed explanations of experimental procedures and include as much detail as possible.
- Graphical work should be carefully attempted and checked. Candidates should use a sharp pencil when plotting data points and use a transparent 30 cm ruler when drawing the line of best fit and the worst acceptable line; care is also 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

Candidates were able to access all parts of the paper and there was no evidence that the paper could not be completed in the time available.

Question 1 involved a typical laboratory experiment and tested the technique of measuring time periods of oscillating bodies. The question required candidates to identify variables and constants from the given equations and give details of their measurements. A significant number of candidates selected the radius of curvature of the track as the independent variable and a few candidates described the basic simple pendulum ignoring the track altogether. Description of the experiment has improved, but graphical analysis would still benefit from more attention. Few marks were scored for additional detail—often irrelevant points were made e.g. "parallax" without explanation. There are always additional detail marks available; candidates should be encouraged to write their plans including appropriate detail.

Question 2 required candidates to plot a graph using negative points to produce a negative gradient. Some careless errors were encountered in the table of results, the plotting of points and the reading of coordinates for the calculation of the gradient. Many candidates were able to determine the gradient and y -intercept and the corresponding uncertainties correctly. Common mistakes included confusion with minus signs and powers of ten.

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 Site.

Comments on specific questions

Question 1

Candidates were required to design a laboratory experiment to investigate how the time period of oscillation of a ball on a curved track changes with the radius of the ball. Candidates were also required to explain how the results could be used to obtain an expression for the radius of curvature of the track using graphical analysis.

The initial marks were awarded for correctly identifying the independent and dependent variables. Several candidates thought that the radius of curvature of the track was the independent variable, perhaps suggesting that they had not read the question carefully. Further credit is then available for controlling variables: candidates should indicate how a fair test could be carried out by keeping appropriate variables constant. As has been indicated in previous reports, it is expected that candidates will explicitly identify the variables that need to be kept constant; “controlled” is not an acceptable alternative to the word “constant”.

Five marks are available for methods of data collection. Candidates were expected to draw a labelled diagram for this investigation which needed to include a method for supporting the track. Many diagrams did not have sufficient detail. Diagrams have to be realistic in showing a workable laboratory set-up, and labelling is vital.

To investigate the relationship, candidates needed to indicate how the time period and radius of ball were measured. To determine the period T , candidates were expected to state how the time would be measured as well as indicating how the period would be determined from timing many oscillations. Micrometers and vernier calipers measure diameter so radius is obtained by dividing by two. Extra credit was awarded for repeating and averaging time periods and radii; for these ‘repeat’ marks, candidates needed to describe explicitly what was been repeated. Statements such as “I will repeat the experiment” did not gain credit.

Within the methods of data collection, candidates should also include additional detail. In addition to the points already mentioned above, credit was also given for using G-clamps for more stability of the supports, realising that the balls have to be of the same density/material, cleaning the track/balls (but not oiling or lubricating the track) and the use of a marker to assist with counting the number of oscillations (but not to start the oscillations in the same place).

The majority of candidates did understand which graph to plot but only a small minority were able to score the second mark relating the gradient and intercept to obtaining a value for C . For this mark to be scored, C was expected to be the subject of the formula. Some candidates suggested plotting T against r ; similarly, logarithmic graphs were not awarded credit. Candidates may only score the additional detail marks if the graph plotted is correct. In this case, candidates were expected to state that if the relationship was valid then a straight line with a y -intercept would be expected.

There was one mark available for describing an appropriate safety precaution. Candidates should be encouraged to give clearly reasoned safety precautions that are relevant to the experiment; candidates were expected to describe a safety precaution related to balls escaping on to the floor.

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 voltage V is affected by the resistance Q of a resistor in an op-amp circuit.

- (a) This was generally answered well, the most common error being the omission of the minus sign.
- (b) A number of candidates lost credit for rounding errors. Two or three significant figures were allowed for the V/E and $1/Q$ columns. Determining the absolute uncertainty in V/E proved difficult for several candidates. Many candidates did not allow correctly for the quotient, e.g. $\frac{\max V}{\min E}$ or $\frac{\min V}{\max E}$.
- (c) (i) Plotting was well done with only a very small number drawing unacceptably large points (‘blobs’). The error bars were generally correct. Candidates should check their plotting carefully.
- (ii) The line of best fit was well drawn in the vast majority of scripts. The worst acceptable line was not drawn accurately enough by a significant number of candidates. It is helpful to use a transparent ruler. A few candidates did not label the lines.

- (iii) This part was generally answered well. Most candidates clearly demonstrated the points they had used to determine the gradient. A few candidates did not use a large triangle for their read-offs from the graph. The method of obtaining the uncertainty in the gradient was generally clearly set out.
- (iv) Some candidates did not realise that there was a false origin. The equation $y = mx + c$ must be used to find the y -intercept by substituting the calculated gradient value and a data point read from the drawn straight line. Often candidates are not awarded credit because they have used a data point from their table of results rather than a point from the line.
- (d)(i) The value of P should be obtained by substitution into the expression for the y -intercept, but credit was not awarded to several candidates who did not include the unit. Several candidates were not awarded credit for the value of R because it was out of range, did not have the correct power of ten, or had too many significant figures.
- (ii) For this part it is essential that candidates show their working. Many candidates did not appreciate that the percentage uncertainty in P is the sum of the percentage uncertainties in the gradient (or R) and y -intercept. Some candidates worked out the absolute uncertainty in P in (d)(i) and continued to find the percentage uncertainty in P . There were some scripts that showed no working and others contained much crossing out that could not be read. Some candidates attempted to work out the maximum or minimum value but did not use the correct combination of maximum and minimum values. Appropriate methods are shown in the published mark scheme.

PHYSICS

Paper 9702/52

Planning, Analysis and Evaluation

Key messages

- In **Question 1**, candidates' responses should include detailed explanations of experimental procedures and include as much detail as possible.
- Graphical work should be carefully attempted and checked. Candidates should use a sharp pencil when plotting data points and use a transparent 30 cm ruler when drawing the line of best fit and the worst acceptable line; care is also 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

Candidates were able to access all parts of the paper and there was no evidence that the paper could not be completed in the time available.

In **Question 1**, a significant number of candidates did not realise how to change the frequency of the alternating current supplied to the coil. Candidates also found **Question 2** difficult, and weaker candidates struggled with the negative intercept in **(a)**.

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, drawing straight lines and not reading off information from the graph correctly. To gain maximum marks, it is essential that candidates show all of their working clearly.

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 Site.

Comments on specific questions

Question 1

Candidates were required to design a laboratory experiment to investigate how the magnetic flux density B in the centre of two parallel coils varies with the radii of the coils and to determine a value for the constant μ_0 .

The initial marks were awarded for correctly identifying the independent and dependent variables. Many candidates correctly realised that the radii of the coils was the independent variable and the magnetic flux density was the dependent variable. Some candidates suggested varying the distance of the Hall probe from the coils.

Further credit is then available for controlling variables: candidates should show how a fair test could be carried out by keeping appropriate variables constant. As has been indicated in previous reports, it is expected that candidates will explicitly identify the variables that need to be kept constant; "controlled" is not an acceptable

alternative to the word “constant”. In this case credit was available for keeping the current constant and keeping the number of turns on the coils constant. Stronger candidates were able to score an additional detail mark for describing clearly a method to keep the current constant—to gain this mark candidates needed to indicate a method of changing the current (use of a rheostat) and a method of checking the magnitude of the current (use of an ammeter).

Five marks are available for the methods of data collection. Candidates were expected to draw a labelled diagram for this investigation. Circuit diagrams must be correct, and clearly labelled using conventional symbols. Incorrect diagrams often omitted the correct position of the Hall probe at the centre of the two coils. Circuit diagrams should have had an ammeter to measure current. A significant number of diagrams indicated incorrectly an a.c. power supply or had voltmeters and/or cathode-ray oscilloscopes in series with the power supply. Some weaker candidates drew a large circuit containing the power supply connected to the coils and the Hall probe.

To investigate the relationship, candidates needed to indicate how both the output of the Hall probe and the radius of the coils could be measured. A large number of candidates stated that the Hall probe would be connected to a voltmeter or cathode-ray oscilloscope, and this was sometimes indicated on the diagram. Most candidates were able to suggest either a ruler or vernier calipers to determine the diameter of the coils. A micrometer was not given credit. Candidates could have gained an additional detail mark for repeating the measurements of diameter and finding an average.

Within the methods of data collection, candidates should also include additional detail. Credit was given to candidates who suggested the use of a large current and/or large number of turns so as to increase the strength of the magnetic field. Other additional detail marks were available for keeping the Hall probe at right angles to the direction of the magnetic field and describing a method to ensure that it was perpendicular. There was also a mark available for repeating the measurement of B with the Hall probe reversed and finding the average. Candidates could also have gained credit for explaining how the coils were checked to ensure that they were parallel and aligned—again detailed explanations are needed.

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. Most candidates realised that a graph of B against $1/r$ should be plotted, although a significant number of candidates suggested incorrectly a graph of B against r . Some candidates suggested that a $\lg B$ against $\lg r$ graph should be plotted. The second mark was awarded for explaining how the gradient of the graph could be used to determine a value for μ_0 . To gain credit here, candidates needed to make μ_0 the subject of the expression. There was also an additional mark available for stating that the relationship would be valid if the data points on the graph were a straight line passing through the origin; some candidates did not state that the line had to be straight. Candidates who suggested that a $\lg B$ against $\lg r$ graph should be plotted needed to state the gradient of the straight line (-1) to gain this additional detail mark.

There was one mark available for describing an appropriate safety precaution. Candidates should be encouraged to give clearly reasoned safety precautions that are relevant to the experiment; candidates were expected to describe a safety precaution relating to the hot coil. Candidates who mentioned electrocution or burning due to the wires were not awarded credit.

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 time t for several oscillations of a pendulum is affected by a distance d .

- (a) Most candidates were able to answer this question correctly, but a number of candidates did not realise that the gradient was negative.
- (b) Most candidates correctly included the column heading, although some candidates did not include a distinguishing mark between the quantity and unit. Some candidates lost credit because of rounding errors. It is expected that the number of significant figures in calculated quantities should be the same as, or one more than, the number of significant figures in the raw data; in this case t

was given to three significant figures so it was expected that T^2 would be given to three or four significant figures.

- (c) (i)** Candidates should be advised to ensure that the size of the plotted points is small; large 'blobs' are not awarded credit. 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)** Some candidates were careless in their drawing of the lines; candidates should be encouraged to use a transparent 30 cm ruler. They should also 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 all 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 were not awarded credit for their lines since they were not straight.
- (iii)** This part was generally answered well; most candidates clearly demonstrated the points they had used to determine the gradient. Some candidates did not use a sensibly-sized triangle for their gradient calculation. A large number of stronger candidates clearly indicated the points that they used from the line of best fit. Some candidates used their points from the table but did not gain credit because they did not lie on the line of best fit.

To determine the 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 used from the worst acceptable line. Some candidates were confused by which line was the best and which was the worst.

- (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 uncertainty in the y -intercept, candidates need to determine the y -intercept from the worst acceptable line. A point from the worst acceptable line and the gradient of the worst acceptable line needed to be substituted into $y = mx + c$. Often weaker candidates attempted a fractional method or just stated an arbitrary value.
- (d) (i)** Candidates needed to determine values for g and k using their gradient and y -intercept values. A large number of candidates either omitted the unit or gave wrong units. Candidates' values of g needed to be given in a specific range in order to gain credit and their answer had to be to an appropriate number of significant figures.
- (ii)** For this question it is essential that candidates show their working. A large number of candidates confused the uncertainty in gradient with the uncertainty in g . To determine the percentage uncertainty in k , candidates needed to add the percentage uncertainty in the gradient (or g) to the percentage uncertainty in the y -intercept. Some candidates subtracted percentage uncertainties while other candidates attempted to work out the maximum or minimum value but did not use the correct combination of maximum and minimum values. Appropriate methods are shown in the published mark scheme.

PHYSICS

Paper 9702/53

Planning, Analysis and Evaluation

Key messages

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