PHYSICS

Paper 9702/11
Multiple Choice

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

General Comments

Candidates should be advised never to spend a disproportionately long time on any one question. Candidates should also be encouraged to use the spaces on the question paper for their working. Care with units is essential. Prefix errors and mistakes with powers of ten are a cause of many wrong answers. It is helpful to look critically at any answer to see if it makes basic sense.

Question 22 was found to be relatively straightforward and **Questions 3**, **17** and **29** were found to be difficult.

Comments on Specific Questions

Question 3

This somewhat unusual question was difficult. Candidates needed to realise that the different units would cause the value of speed in kilometres per hour to be 3.6 times larger than the value in m s^{-1}. Since v is squared, the required answer is $k_1 / 3.6^2$ which is $0.0772\, k_1$.

Question 7

Many candidates gave answers **A** and **B**. Neither of these graphs shows terminal velocity, which is a line of constant (and non-zero) gradient on a displacement-time graph. The flat section of **C** suggests that the sphere is stationary, so this also cannot be correct.

Question 13

The most important fact in answering this question is that a total mass of 10.0 kg is being accelerated (not 8.0 kg). A common error was to solve (2.0 × 9.81 – 6.0) = 8.0 *a* for the acceleration *a*, which gives the incorrect answer **B**.

Question 16

Many candidates chose **D**. This shows that candidates must be particularly careful with powers of ten.

Question 17

Candidates found this question difficult. Many chose **B**, but this ignores both the frictional drag on the car and the fact that the power from the engine does more than just increase the potential energy of the car. The correct answer is **C** because all output power is useful in this situation.

Question 19

This was also a difficult question. The kinetic energy of the sand does increase by $\frac{1}{2}mv^2$ but this cannot be the only power involved (it would imply an infinite acceleration for every grain of sand landing on the belt). A better approach is to consider momentum. In one second, the momentum of mass *m* of sand increases from zero to *mv*, so the force involved is *mv* and the power required is mv^2.

Question 23

The length is increased from 2.0 cm to 3.0 cm so the extension is increased from 1.0 cm to 2.0 cm. The area beneath the graph is therefore 3.0 N × 0.01 m = 0.030 J.

Question 29

There is a stationary wave (resonance) in the tube when there is a node at a sealed end and an antinode at an open end or at the loudspeaker (which is at an open end). The only answer that satisfies this condition is **D**. Many candidates chose **C** but this length of tube could support a stationary wave only if the right-hand end was open.

Question 32

This question required careful reading. Many candidates took *V* rather than 2*V* as the potential difference across the plates.

Question 36

A simple way to approach this question is to consider that the power dissipated in *R* is I^2R and so must be zero when *R* is zero, and must also be zero if *R* is infinite (as the current *I* will then be zero). The power must increase and then decrease as *R* increases from zero. As *R* increases, the current *I* decreases, the potential difference across *R* increases, the potential difference across *r* decreases and the power dissipated in *r* (given by I^2r) decreases.

Question 38

Here the arrangement is effectively a 10 Ω resistor RST in parallel with a 5 Ω resistor RT, and in series with another 5 Ω resistor (XR+TY). The total resistance is therefore 5 Ω + 3.3 Ω = 8.3 Ω.

PHYSICS

Paper 9702/12
Multiple Choice

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

General Comments

Candidates should be advised never to spend a disproportionately long time on any one question. Candidates should also be encouraged to use the spaces on the question paper for their working. Care with units is essential. Prefix errors and mistakes with powers of ten are a cause of many wrong answers. It is helpful to look critically at any answer to see if it makes basic sense.

Questions 2, **5** and **29** were found to be relatively straightforward and candidates found **Question 13** to be difficult.

Comments on Specific Questions

Question 4

This type of question is made easier by drawing on the question paper, and candidates should be encouraged to do this. When drawing the resultant of the each of the two vectors shown, it becomes clear that the sum of the two vectors in **C** has a downward direction so cannot equal vector R.

Question 6

This question involving both random and systematic error was challenging. The zero error can be removed but its uncertainty must be added to the measurement uncertainty, so the four sheets have a true thickness of (1.00 ± 0.04) mm. A single sheet would have a thickness of (0.25 ± 0.01) mm. This has a percentage error of 4%.

Question 8

Many candidates incorrectly chose **B**, suggesting that they were considering air resistance to be significant. Candidates should take care to read the question carefully.

Question 10

A common mistake was to assume that the mass of the rocket is constant. The mass of the rocket must reduce as the fuel is burnt and so the acceleration increases until there is no fuel left.

Question 13

Candidates found this question to be particularly difficult, suggesting that they would benefit from further work on Newton's third law. It is essential to realise that the two equal and opposite forces must act on different bodies and they must be the same type of force (gravitational or contact/electrostatic in this case).

The weight of the book is the gravitational force exerted on the book by the Earth. The equal and opposite force to this is the gravitational force exerted on the Earth by the book. The contact force on the table is the force exerted on the table by the book and the equal and opposite force to this is the contact force exerted on the book by the table. Four forces are involved, of which two forces act on the book. If the weight of the book is the 'action' force, it must have a 'reaction' that is also a gravitational force, so the reaction is the gravitational force exerted on the Earth by the book.

Question 16

The water flows between X and Y at constant speed, so its kinetic energy does not increase. The loss of potential energy must be balanced by an increase in elastic potential energy.

Question 19

Candidates should be reminded that, whether molecules are in the solid or liquid state, they have the same average kinetic energy and same average speed when they are at the same temperature.

Question 22

The elastic limit is just beyond the limit of proportionality, so **B** is correct.

Question 23

This is a difficult question. Because the wall is thin in comparison with the diameter of the tube, the area of the annulus is proportional to w. To halve the stress, w must be doubled.

Question 34

Many candidates incorrectly chose **A**. This cannot be correct because some energy will be dissipated in the internal resistance of the cell.

Question 37

A simple approach is to ignore the parallel 2.0 Ω resistor in the middle. There is a potential difference of 2.0 V across 4.0 Ω total in the lower branch, so the current in this branch is 0.5 A. Half of this gives I as 0.25 A.

PHYSICS

Paper 9702/13
Multiple Choice

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

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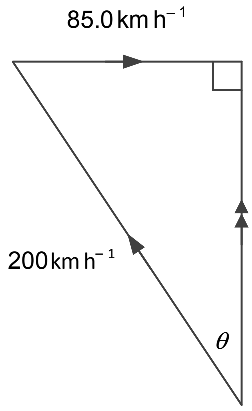
Comments on Specific Questions

Question 3

Candidates found this question difficult. The vector diagram below shows the situation. The angle θ is given by 85.0 = 200 sin θ.



Question 13

Many candidates chose **A**, but this is not the height above the ground. It is important that candidates read the question carefully before selecting their answer.

Question 14

This question can be answered quickly by realising that the upthrust is the weight of water displaced. Once this is established, it becomes clear that the upthrust will be the same on each of the cuboids.

Question 15

Constant velocity implies $X = Y + Z$. The weight of an air bubble is tiny so this must be Y. The upthrust must be X as it is the only force with the correct direction, so Z must be the drag.

Question 19

Candidates found this question difficult. Initially force F acting over distance s gives an extra 4.0 J of kinetic energy. With double the force and double the distance an extra 16 J is provided, so the total kinetic energy changes from 4.0 J to 20 J. Many candidates chose **A**, suggesting that they had correctly calculated 16 J but did not read that the question asks for the final energy, not the increase.

Question 21

This relatively complex situation was correctly interpreted by most candidates.

Question 26

Particular care is needed with this type of question, which requires interpretation of graphs. At the earliest time there is a sudden jump up, followed by a constant high value of s and finishing with the negative peak. The answer is therefore **D**.

Question 29

The amplitude of oscillation at Z is zero, so destructive interference occurs at Z and the difference between lengths XZ and YZ (10 cm) must be an odd number of half-wavelengths. Only **C** satisfies this condition with 5 half-wavelengths.

Question 36

One method to answer this question would be to draw the battery and voltmeter in each of the four circuits. A common incorrect answer was **C**. In this circuit, a wire connects Q and R so these points must be at the same potential, and a voltmeter between these points will read zero.

Question 37

This question requires care, and candidates should be advised to avoid attempting to use ratio methods. The total resistance of the circuit is 0.588 Ω, and this can be used to determine the potential difference across the resistors, which is 2.94 V. The current in the 2.0 Ω resistor is therefore 1.5 A.

Question 38

Each of the possibilities must be considered separately before coming to a conclusion. Emission of an α-particle reduces the number of neutrons in a nucleus by 2. Emission of a β-particle reduces the number of neutrons by 1. Emission of a γ-ray does not change the number of neutrons.

PHYSICS

Paper 9702/21

AS Structured Questions

Key messages

- Candidates should choose their wording carefully, especially when giving a definition or describing a situation. Often answers are made unclear through the omission of certain key words and inappropriate use of everyday language.

- When answering questions where an explanation of a specific situation is required, candidates should be reminded to give detailed answers. Full credit cannot usually be awarded for a statement of general theory that does not relate to the situation in the question.

- Some credit is awarded for the application and extension of the content of the syllabus. In order to score highly, candidates need to have a thorough understanding of the subject matter so that they can discuss sensibly situations that are based on the theoretical work.

- Some candidates quote formulae without giving a subject. It is not always possible for the Examiner to know what is intended by the candidate, especially when subsequent working is not wholly correct, and as a result it may not be possible to award credit. Candidates should be encouraged to show clearly the subject of all formulae used.

General Comments

There were many instances where candidates lost credit either through not reading graphs correctly or through poorly drawn graphs. Candidates should be encouraged to pay careful attention to both of these aspects when answering questions.

Some candidates did not answer all parts of all questions. However, there was no evidence that adequately prepared candidates had insufficient time to complete the answers.

Comments on Specific Questions

Question 1

(a) The outcome of the task was provided in the question stem. Credit was awarded for clear explanation. Most candidates started by giving an appropriate expression for power. Where this expression was given in term of symbols, then symbols should be explained. Such explanation is essential where the symbols are not the conventional symbols. For example, it was quite common to find that the numerator of the expression was given as "*wd*", and it was not clear whether this was "work done" or "energy × distance".

(b) Most candidates successfully derived the units. A significant number used an expression for potential as the starting point rather than an expression for electrical power.

Question 2

(a) Speed and velocity may best be defined in terms of rate of change of distance/displacement with respect to time. In many scripts a ratio was given. Where such a ratio is involved, candidates should be discouraged from using loose wording, such as "over time" or "with time".

Some explanations were inadequate because they included only a reference to distance as a scalar and displacement as a vector. It was expected that explanations would include the terms “magnitude only” and “magnitude and direction”.

(b) (i) It was expected that candidates would identify the relevant time intervals together with constant acceleration, rebound and also deceleration to zero speed with the same magnitude as the acceleration. There were few complete answers. In general, the majority of answers were limited to a satisfactory identification of the rebound.

(ii) The majority of answers were correct. It was common to find that, although a correct expression was quoted, either the graph scales were read incorrectly or there was a power-of-ten error.

(iii) 1. In the majority of answers, it was realised that the distance should be calculated from graph areas and that more than one area is involved. A common mistake was to read the graph scales incorrectly. In some other answers, incorrect areas were identified.

2. Where a correct answer had been given in **part 1** then, in general, this part was completed successfully.

(iv) Many candidates found it difficult to draw the correct graph shape. The most common errors were either to omit the section showing the rebound or to indicate times where the speed was constant.

Question 3

(a) There were very many correct answers. A small number of candidates made errors associated with incorrect directions for the momentum.

(b) Many answers were incorrect. Most candidates made a reference to kinetic energy conservation but did not make it clear that they were discussing total kinetic energy. Where the answer was given in terms of speeds, very few mentioned *relative* speed of approach/separation.

(c) Most answers included statements of Newton’s second and third laws but, for the third law, many did not apply the law to this situation. Rather, a general statement was given. A reference to the time of collision being the same for both balls and the relevance of this to rate of change of momentum was rarely seen.

Question 4

(a) (i) There was a general misconception that a straight line graph automatically implies proportionality between two quantities. Candidates were expected to consider the coordinates at two points, taking the ratio of the values at each point and showing that this ratio is constant.

(ii) Power-of-ten errors were very common.

(iii) A correct expression, energy = $\frac{1}{2}kx^2$ or $\frac{1}{2}Fx$, was quoted in most answers. Many candidates realised that the energy is represented by the area below the line of the graph. In many instances, the area calculated was the area below the line on Fig. 4.2, without taking into consideration that the origin is not shown on this graph.

(b) Generally, the calculation of the speed was correct, when based on the candidate’s answer in **(a)(iii)**.

Question 5

(a) A common misconception was that zero current means zero resistance. Some candidates incorrectly thought that the gradient of the line represents resistance.

(b) Candidates should be reminded that, when sketching a graph, the important features should be included. Many lines were not correct. It was expected that the line would pass through the origin, be straight initially and then curve indicating a decreasing gradient, without the gradient becoming zero. Of those who did produce a satisfactory curve, very few drew the line in the both first and third quadrants.

(c) (i) This calculation presented very few problems.

(ii) This was completed successfully by the majority of candidates. The most common error was to assume that there was no internal resistance in the power supply. Candidates should be encouraged to read the question carefully.

(d) Most answers contained a correct statement that resistance increases as current increases.

Question 6

(a) Terms such as "spreading" were used when referring to diffraction. Very few answers incorrectly referred to refraction. Most answers for interference did include waves meeting at a point. Very few went on to discuss interference in terms of the addition of displacements.

(b) In general, relevant formulae were quoted. There was some confusion as regards "lines per millimetre". Power-of-ten errors gave rise to some answers which were inappropriate. There may have been some doubt as to the meaning of "orders of diffracted light" and, consequently, answers of 3 or 6 orders were accepted.

(c) Generally, candidates who had shown understanding of the concepts in earlier parts of this question were able to give a satisfactory answer.

Question 7

(a) There was some confusion between electric field and electric field strength. It was expected that reference would be made to a region of space where charge experiences a force.

(b) (i) Candidates should be encouraged to use a straight edge when drawing straight lines. Frequently, the pattern was drawn poorly and only the mark for direction could be awarded. It was expected that equally-spaced, parallel lines would be drawn.

(ii) This was generally answered correctly but some candidates made power-of-ten errors.

(iii) There were some very well explained correct answers. It was common to find that an incorrect value for charge was used, and in some cases work done was confused with force on the α-particle.

(iv) It was expected that working would be shown. In some answers, large volumes of algebra were given, leading to answers which were unrealistic. Others did realise that the ratio would be the ratio of charges and gave the answer, with or without explanation.

PHYSICS

Paper 9702/22
AS Structured Questions

Key Messages

- Candidates should choose their wording carefully, especially when giving a definition or describing a situation. Often answers are made unclear through the omission of certain key words and inappropriate use of everyday language.
- When answering questions where an explanation of a specific situation is required, candidates should be reminded to give detailed answers. Full credit cannot usually be awarded for a statement of general theory that does not relate to the situation in the question.
- Some credit is awarded for the application and extension of the content of the syllabus. In order to score highly, candidates need to have a thorough understanding of the subject matter so that they can discuss sensibly situations that are based on the theoretical work.
- Some candidates quote formulae without giving a subject. It is not always possible for the Examiner to know what is intended by the candidate, especially when subsequent working is not wholly correct, and as a result it may not be possible to award credit. Candidates should be encouraged to show clearly the subject of all formulae used.

General Comments

The questions that involved calculations were generally well presented and were completed correctly by the majority of candidates. Examples of such calculations were in **Questions 2**, **3** and **5**. Questions that required an explanation of a specific example were often not answered with sufficient precision. Generally only the basic theory was stated and this was often too vague and did not give the details required, particularly in **Questions 4** and **6**. Candidates should be made aware that it not sufficient to repeat a general theory. The theory should be applied to the specific example in the question.

Comments on Specific Questions

Question 1

(a) This question was generally well answered. The majority of candidates were able to derive the correct base units for energy from the definition for work done. A small minority ignored the instruction given in the question to use an equation based on the definition of the work done, and instead used an expression for power or kinetic energy.

(b) A common mistake was to define potential difference in terms of energy transferred “by unit charge” or “by one coulomb”, without reference to dividing energy by charge. In general, candidates correctly understood that potential difference involves the transfer of electrical energy to other forms of energy. Some candidates either gave no response or an equation involving potential difference such as current × resistance.

(c) A significant number of well-prepared candidates were able to produce a correct solution. The majority of candidates were able to start with an expression for resistance. Candidates who started with $R = P / I^2$ were generally more successful than those who started with $R = V / I$. Some candidates incorrectly considered the coulomb as a base unit. There were a number of errors made such as cancelling A as numerator with A^{-1} as a denominator.

Question 2

(a) There were a significant number of answers that suggested that the candidate had not read or realised that the graph represented displacement against time. Their answers seemed to describe a velocity against time graph, suggesting that they would benefit from more careful reading of the question. The description given by some candidates also seemed to ignore that the graph represented a stone that had been thrown vertically upwards. The description suggested that the stone had constant velocity for the first and last parts of its path. A significant number of answers suggested that at time t = 0 the speed was zero and that the speed then increased but was zero at the maximum displacement. The descriptions of the speed were often not related to the correct times and therefore credit was not awarded.

(b) (i) The majority of candidates were awarded credit for the initial equation, but many candidates could not be awarded further credit because they assumed the initial velocity was zero and used the total time of 3 s in their calculation. Stronger candidates produced well-presented correct solutions.

(ii) Many candidates attempted to calculate the total distance in one calculation using one equation of motion. These candidates did not realise that the equations of motion gave them the displacement and could not give the total distance travelled in the 3 s. Many of these candidates also assumed the velocity was zero at t = 0 and t = 2.5 s. The more able candidates gave the values for the known quantities at each of the three stages and generally completed the calculation successfully. The use of g = 10 was less common than in previous series.

(iii) Many candidates found it difficult to interpret the graph and the information given to obtain correct answers in **(i)** and **(ii)**, and also found this part difficult. These candidates were unable to interpret the displacement time graph and were not able to distinguish between distance and displacement. Candidates with calculations in **(ii)** involving the displacements for the three stages were usually able to calculate a correct displacement. The majority of candidates realised that the displacement was downwards. Many weaker candidates who were unable to calculate a value were able to deduce the direction from the graph.

(c) There were many correct answers from the candidates who had gained credit in **(b)**. These candidates produced a velocity-time graph with a constant negative gradient throughout showing a good understanding of the motion of the stone. A very small minority gave a line with a positive gradient. There were many responses that indicated a non-uniform acceleration, even from candidates who had used equations of uniform acceleration in **(b)**.

Question 3

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

(ii) Most candidates gained credit. A very small number gave reversed answers to **(i)** and **(ii)**. A few candidates did not gain credit as they gave 44 cos 30 or $22\sqrt{3}$ as their answer. Candidates should be reminded that numerical values should always be worked out.

(b) There was a majority of correct answers. A small minority gave an incorrect distance for the vertical component of F from the point P, or used the value 44 N for F.

(c) The majority of candidates referred only to the conditions required for equilibrium or gave a general statement of Newton's third law. Reference to the specific problem was required in order to gain full credit. The majority of candidates who gained credit described the need to balance the horizontal component of the force F. Very few candidates referred to the imbalance of the vertical forces.

(d) The majority of candidates incorrectly drew a horizontal or vertical arrow. Candidates should be advised that if the instruction in the question is to draw on a particular figure, then it is important to do this. Credit could not be awarded if the arrow was not on Fig. 3.1.

Question 4

(a) The majority of candidates obtained the correct value for the change in momentum. Weaker candidates were often able to gain partial credit for the expression for momentum, but then either gave the initial momentum or subtracted and obtained zero change in momentum.

(b) (i) A significant number of candidates described the change in momentum of a molecule when colliding with a wall. The relationship between the force and change in momentum was described by fewer candidates. A small minority went on to describe the effect of many collisions by a large number of molecules contributing to the average force over the area of the walls and hence the pressure. Some candidates referred only to a collision producing a force with no mention of momentum. This collision was often between molecules rather than with the wall of the container. Some weaker candidates described the effects on the pressure of changes in temperature or volume.

(ii) There were very few correct answers. The majority of answers suggested that there would be more molecules or more collisions but did not go on to state that the frequency of collision would increase. A common misconception was to suggest that the molecules had a greater mass or greater speed. A significant number related the pressure in a liquid with the density of the liquid and did not answer the question.

Question 5

(a) Many candidates drew the correct graph. There were a large number of candidates who drew a straight line with either a positive or negative gradient. Other common causes of lost credit were to draw a curved line with a significant section parallel to the temperature axis, showing zero resistance at high temperatures, or being vertical at low temperatures.

(b) (i) Many candidates repeated the statement in the question. This was either in terms of Kirchhoff's second law or in general terms of energy conservation. There was no explanation of why the energy transformed in the battery was equal to the energy transformed in the three resistors, which required reference to the internal resistance of the battery.

(ii) This numerical question was generally well answered. The majority of candidates selected the correct potential difference across the relevant resistor and obtained the correct circuit current. Weaker candidates often did not read the information carefully and selected an incorrect potential difference for a particular resistor or ignored the power of ten given in the resistance values.

(iii) This was also generally well answered. The majority of candidates calculated the total resistance of the circuit and then subtracted the sum of the resistances of Y and Z. The more able candidates were able to complete the calculation successfully using a potential divider expression.

(iv) Stronger candidates realised that the current would increase owing to a decrease in the resistance of the thermistor. A more common, but incorrect, answer was to relate a decrease in resistance with a decrease in potential difference while assuming the current remained constant.

Question 6

(a) The majority of candidates were awarded credit for the difference in terms of energy transfer. Full credit was not often given. A large number of candidates described stationary waves in vague terms of nodes and antinodes or being formed by two waves. A minority of candidates were able to describe the difference in terms of amplitude or phase. There were some answers that only described a property of one type of wave with no reference to the second type of wave.

(b) (i) The majority of candidates did not gain full credit for this part as the descriptions given were in general terms and not with reference to the apparatus in the question. Weaker candidates referred to the source emitting sound waves or did not describe the origin of the waves that travelled to the reflector.

(ii) The movement of the detector in the correct directions to observe maximum and minimum deflections on the meter was described by only a small minority of candidates. Many candidates did not describe moving the detector. The detection of stationary waves was often incorrectly described in terms of the reading on the meter oscillating when the incident and then the reflected waves passed the detector. Many candidates stated that the meter would not show any deflection when stationary waves were formed. The detection was often described in terms of nodes and antinodes being seen, rather than what was observed on the meter.

(iii) Many answers were not precise enough to gain credit. These answers did not describe the measurement of the distance between adjacent nodes or antinodes. The distance “from one node to another node” is not precise enough to suggest how the wavelength can be determined from this method. The distance has to be measured in some way and only the distance between successive nodes or antinodes, or a number of successive nodes and antinodes, can be properly related to the wavelength. There were some answers from weaker candidates that suggested measuring the speed and frequency of the microwaves to determine the wavelength.

(c) This question was generally well answered. The majority of candidates gave the correct frequency in GHz. Weaker candidates had difficulty converting Hz to GHz or substituting a value for the speed of the microwaves.

Question 7

(a) A significant number of candidates included 92 electrons or only stated neutrons and protons without any numbers being included.

(b) The majority of the candidates obtained at least partial credit. The weaker candidates were generally unable to determine the numbers required.

(c) A significant number gave at least one of the possible correct answers.

(d) This question was difficult and was correctly answered only by the very able candidates. The majority of candidates merely restated what was in the question. They referred to the conservation of mass-energy without discussing the actual nuclear reaction in this question. The total mass on the left-hand side of the equation was rarely compared to the total mass on the right-hand side.

PHYSICS

Paper 9702/23
AS Structured Questions

Key Messages

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Comments on Specific Questions

Question 1

(a) This question was generally well answered. A small minority of candidates were unable to convert the distance given into Gm. The conversion of the distance using 10^6 or 10^{-6} was a common source of errors.

(b) The majority of candidates made mistakes with this calculation using speed = distance / time. A significant number of candidates were unable to obtain the correct distance for the signal to travel to the satellite and back. Errors were made by not subtracting the radius of the Earth, not converting the powers of ten correctly and ignoring the distance for the return of the signal. The weaker candidates were unable to substitute the correct speed for microwaves.

(c) The majority of candidates were able to give the correct base units for the quantities velocity, density and pressure. Errors were sometimes made rearranging the equation and when cancelling indices. A significant number of candidates arrived at an incorrect conclusion that *C* equalled zero or one instead of showing that *C* had no unit.

(d) The majority of candidates gave the correct answers. A significant number of candidates actually gave the vector quantities, so either had confused vectors with scalars or misread the question.

(e) (i) This question was generally well answered. Candidates tended to lose credit for not including arrows on their vector triangle or inserting an arrow for the direction of the boat that showed the boat returning to the river bank. There were some candidates who ignored the instruction to draw a vector triangle on Fig. 1.1. These candidates could not be given full credit. Candidates should be advised that, if the question asks for information to be added to a figure, then the addition should be made on that figure and not on a redrawn diagram.

(ii) A significant number of candidates obtained the correct answer by drawing a scale diagram. There were only a minority of candidates able to obtain the answer by calculation. These candidates used the cosine rule or resolved the velocity vectors. There was an assumption made by some candidates that the boat went directly across the river and that the triangle was a right-angled triangle. This was not a valid solution.

Question 2

(a) The majority of candidates obtained credit for describing the first part of the motion from $t = 0$ to $t = 8$ s. The weaker candidates lost credit by omitting to state that the acceleration was constant. The majority of candidates did not gain credit for their description of the second part of the motion. The statements either suggested that the direction of motion of the ball changed at 8 s or the times were not given as $t = 8$ s to $t = 16$ s for the constant deceleration. A significant number of candidates misread the graph and stated that the velocity reached $16\,\text{m}\,\text{s}^{-1}$ in the final stage.

(b) (i) This was well answered by the majority of candidates. A small minority calculated the displacement by subtracting the displacement for the time $t = 8$ s to $t = 10$ s from the displacement for the first 8 s. These candidates considered that the change in direction occurred at 8 s even though the velocity was still in the same positive direction.

(ii) The majority of candidates answered this correctly. The weaker candidates did not realise that the acceleration at 10 s was the same as that for the motion from 8 s to 16 s and tried to use the velocity at 10 s to calculate the acceleration.

(iii) This was well answered by the majority of candidates. A small minority used the velocity at 8 s as the maximum velocity (the peak of the graph) and a few did not convert the mass into kg.

(c) This was well answered only by the more able candidates. The majority of candidates did not realise that the ball started to move back to point P after 10 s. There were some candidates who calculated the time taken to move back to P but did not include the time taken to get to P in their final answer.

Question 3

(a) A significant number of candidates gave a definition in which it was not clear that power is work done per unit time. Candidates should be advised not to use expressions such as “over time”, “in a certain time” or “in a unit of time”.

(b) (i) This calculation was well answered by a large majority of candidates. A small minority calculated the resultant force and gave this as the force required from the car, ignoring the resistive force.

(ii) This was well answered by the majority of candidates. A significant number were unable to start with an equation that linked power with the speed of the car.

(c) A small minority were able to explain why the car has a maximum speed. Many candidates described the conditions for terminal velocity. Some answers compared different quantities such as suggesting that the output power was unable to overcome the resistive force or the acceleration becomes equal to the resistive force.

Question 4

(a) (i) A majority of candidates were able to name the instrument for measuring the diameter and length of the wire. The load was often assumed to be given or on the masses themselves. The extension was often measured using calipers even though the values were similar to the diameter. Vague answers like a ruler for the length and a “scale” for weight were given by a significant number of candidates. Blank spaces were left for at least one instrument by a large number of candidates.

(ii) A small minority of candidates explained the reason for taking a series of readings in terms of reducing random errors. A small number suggested using a graph to check for proportionality between force and extension. The majority of answers were too vague to be awarded credit, such as “to determine the strain” or “to determine the Young modulus” (which restates the question). Others made a reasonable suggestion that the values could be used to check whether the elastic limit had been exceeded.

(b) A very small number of candidates suggested using the series of readings to plot a graph and then use the gradient to determine the Young modulus. The majority suggested using one set of values to determine a value for the Young modulus or merely quoted the equations for stress and strain.

Question 5

(a) This was well answered by a large majority of candidates. A very small minority either did not know the correct equation for resistivity or were unable to calculate the cross-sectional area. Candidates should be reminded that the full substitution and working should be shown in “show that” questions.

(b) (i) A large number of candidates were able to complete this calculation. Weaker candidates used the e.m.f. of the power supply for the p.d. across resistor R. A significant number of candidates were able to calculate the resistance of the wire but then made errors in calculating the total resistance for the parallel combination.

(ii) Most candidates gave an appropriate expression for power. There were only a small number who used the correct current or p.d. for the wire AB. The majority used the current determined in **(i)** or the p.d. of the power supply.

(iii) The solution was obtained only by the more able candidates. The majority of candidates were unable to determine the currents through the two parallel sections or the p.d. across the resistors in the two sections. A significant number of candidates left this part blank.

Question 6

(a) (i) This question was well answered by the majority of candidates. A significant number of candidates gave incorrect statements for coherence, referring only to the same frequency, the same wavelength or the same phase.

(ii) This was well answered by the majority of candidates. Some candidates misread the *x*-axis when determining the wavelength and some did not substitute the given value for the speed of the wave.

(iii) A number of candidates gave a distance from the graph or gave a half the correct value.

(iv) A minority of candidates were able to add the two waves successfully. There was a relatively large number of blank answers. This type of exercise should be practised by candidates as it gives a good insight into the principle of superposition.

(b) (i) The majority of candidates were able to determine the distance between the maxima. Only a small number of candidates then went on to determine the distance AB required by the question. A significant number left the question blank or tried to use an incorrect expression.

(ii) This question was well answered by the more able candidates. There was a significant number who either left the question blank, considered blue light to have a longer wavelength than the laser light or gave no explanation.

Question 7

(a) (i) A significant number of candidates confused spontaneous decay with random decay.

(ii) A small minority gave the particles in the nucleus of X. The majority merely stated that X was an α-particle or helium nucleus. These candidates did not appear to have read the question carefully.

(b) (i) A very small number of candidates described the mass on the left-hand side being greater than the total mass on the right-hand side of the equation. Only the strongest candidates were able to equate this difference in mass with the energy released.

(ii) A minority of candidates were able to complete this conversion. There were many blank spaces or attempts that involved incorrect physics. Candidates should practice converting eV into joules and vice versa.

PHYSICS

Paper 9702/31
Advanced Practical Skills 1

Key Messages

- Candidates should be reminded that they should always plot all of their tabulated readings on the graph in **Question 1**. If some of the readings do not fit on the graph grid, then a different scale should be chosen.

- Many candidates find it difficult to choose scales that make good use of the graph grid. The aim should be to occupy the majority of the graph grid. If less than half of the grid is occupied in one direction, the range of the corresponding axis can be halved to make better use of the grid.

- When deciding whether the relationship in **Question 2** is true, candidates should be encouraged to make a quantitative comparison and then make a precise statement consistent with the comparison. A vague phrase such as “within experimental accuracy” is not sufficient.

- 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. Candidates should be encouraged to write about four different problems and consequently four different solutions to address these problems, and should not try to state four solutions to the same problem.

General Comments

Most candidates were confident in setting the circuit up for **Question 1** and manipulating the apparatus for **Question 2**.

Some candidates showed the need for further practical work with electrical circuits and use of meters. When taking a reading from an ammeter, candidates should take particular care to check the scale. In **Question 1** the scale used was 0 to 200 mA therefore values would be of the order of mA, not A.

Centres generally did not have any difficulties in providing the equipment required for use by the 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 when marking. 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 help should **not** be given with the recording of results, graphical work or analysis.

With electrical experiments, Centres need to be vigilant to provide working meters and supplies which are well tested before the examination.

Comments on Specific Questions

Question 1

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

Successful collection of data

(a) (ii) Most candidates attached the crocodile clips and adjusted the length of wire between the clips to approximately 50 cm. The measured length *w* should be recorded with the unit. Taking care with units ensured success, whereas some candidates taking less care received no credit for answers such as 50.4 with the unit omitted or 50.4 m where the unit did not match the number. The length given is to guide the candidate into the experiment. Some candidates missed this information and measured a value outside the required range.

(c) (iii) Looking carefully at the range on the ammeter led to a successful answer e.g. 74.2 mA. Ignoring the ammeter range led to an invalid value such as 74.2 A. Some candidates measured values out of range, but they could be awarded credit if this was close to the Supervisor's value.

(d) Successful candidates collected six sets of values for *w*, I_A and I_B showing that as *w* increased both I_A and I_B decreased. Candidates are advised to think carefully about their technique for taking readings. A consistent set of results with a correct trend could be obtained by starting with a small value of *w* and gradually increasing *w*, rather than increasing and decreasing the length which led to variation in results if not done carefully.

Range and distribution of values

(d) Successful candidates considered the whole length of the 110 cm piece of wire to which they were attaching crocodile clips. Consequently, *w* varied from approximately 20 cm to 90 or 100 cm. Many candidates chose to vary the length by only 50 cm, and some by only 10 cm, and this range was too small to gain credit.

Quality of data

(e) (i) Most candidates who were able to collect a full set of readings were awarded credit for the quality of data.

Table

(d) Many candidates successfully included a quantity with correct units in every column heading. These candidates remembered to include the quantity and a separating mark, such as a solidus, between the quantity and unit. The majority of candidates were comfortable giving *w* / cm and I_A / mA or I_B / A but often omitted the unit for the calculated quantity. Those who attempted a unit for $(I_A + I_B)/I_AI_B$ often successfully gave A^{-1} or 1/A. Some candidates needed to complete their determination of the unit as A/A^2 or $2A/A^2$ did not gain credit. When candidates included a column for I_AI_B they often correctly gave I_AI_B / A^2.

The metre rule provided had millimetre markings and successful candidates used millimetres when recording their values of *w*, e.g. 0.449 m or 32.0 cm. Values recorded as 0.45 m or 32 cm did not gain credit. Candidates lost credit when they added an extra zero and stated *w* values to the nearest tenth of a millimetre e.g. 0.4490 m.

Most candidates were able to calculate $(I_A + I_B)/I_AI_B$ correctly and strong candidates used 3 s.f. in the raw data for current and 3 s.f. in the final value of $(I_A + I_B)/I_AI_B$. Many of the errors in the calculations were due to incorrect rounding of the final value. When considering significant figures it should be the column containing the raw (initial) current readings that is used as the source data.

Graph

(e) (i) Candidates were asked to plot a graph of $(I_A + I_B)/I_AI_B$ on the *y*-axis against *w* on the *x*-axis and good answers gained credit for using axes that were labelled, with scales that were easy to use and with points spreading over more than half the grid.

Considering *w* on the *x*-axis, a scale used by successful candidates used one large square to represent 10 cm so that each small square had a value of 1 cm. An awkward scale on the x-axis was 15 small squares to represent 10 cm, and consequently each square had a value of 0.667 which is not easy to work with and could not be awarded credit.

Successful candidates checked that axes were labelled as $(I_A + I_B)/I_AI_B$ and w. Candidates gained credit for plotting all the tabulated readings accurately to within half a small square. Some candidates can improve by using sharp pencils to draw finer points; any points drawn that have a diameter larger than half a small square are not credited.

(ii) Successful candidates were able to draw a good line of best fit through their six points with points balanced well along the whole length of the line. Candidates were also successful when drawing a line through five trend points with one anomalous point identified. When a point is identified as anomalous for the purposes of drawing the best line, this point should be indicated clearly on the graph, e.g. by drawing a small circle around the point.

Candidates should be advised that, before marking a point as anomalous, they should check that the point is plotted correctly, that the calculation for that point is correct and there is no arithmetical error, and also that their scale increases regularly and there is no gap in values on the axis e.g. 10, 30, 40. They should also check the measurements to be sure the readings were taken and recorded correctly. Only one point, if any, should be identified as anomalous.

When a line is drawn successfully, candidates look at the balance of points. Those candidates who choose to join the first and last points or join up a few points on their line often produce a line which needs to be rotated.

Interpretation of graph

(e) (iii) Many candidates used a suitably large triangle to calculate the gradient, gaining credit for correct read-offs, and substituted into $\Delta y/\Delta x$ to find the gradient. Other candidates needed to check that the read-offs used were within half a small square of the line of best fit, show clearly the substitution into $\Delta y/\Delta x$ (not $\Delta x/\Delta y$), and check that the triangle for calculating the gradient is large enough (the hypotenuse should be greater than half the length of the line drawn).

When taking the read-off to find the intercept, successful candidates checked that the x-value where the read-off was taken was actually at $x = 0$. Often the scale began at, for example, $w = 10$ cm, and the candidate assumed that it was $x = 0$. When making the substitution, care needed to be taken that the x-value and y-value are put into the correct places in the equation. Candidates should take care to use $c = y - mx$ and not $c = y / mx$.

Drawing conclusions

(f) Successful candidates recognised that M was equal to the value of the gradient and N was equal to the value of the intercept calculated in **(e)(iii)**. Consequently, they made a straightforward transfer of the values in **(e)(iii)** to **(f)** and gained full credit. No calculation needed to be done to find M and N. Correct units were given by successful candidates, but some other answers did not have the correct powers for $A^{-1} m^{-1}$ (not A m). Units were often omitted.

Question 2

In this question, candidates were required to investigate the balance of two wooden strips with different lengths.

Successful collection of data

(a) (i) Most candidates successfully recorded a value of L with a consistent unit and in range e.g. 59.1 cm. Successful candidates noticed that they needed to add a unit on the answer line. There were some values of (e.g.) 59 m or just 59.

Measuring the length of the piece of wood was a static observation. Candidates could take all the precautions they needed to produce an accurate measurement, e.g. place the scale close to and parallel with the strip, line up their head with the scale on the metre rule which was accurately calibrated to the nearest mm, and take time to make the observation. Therefore this measurement was not regarded as a source of uncertainty. Many candidates suggested it as a source of uncertainty in the final section, often commenting on zero or parallax errors when using the metre rule to measure L. Neither of these ideas gained credit.

(ii) Many candidates recorded a value of m to the nearest gram.

(b) (i) Many candidates recorded a value of *M* to the nearest gram.

(c) (ii) Successful candidates balanced the strip, recorded distance *x* to the nearest millimetre and stated the unit e.g. 9.7 cm. Recording *x* to the nearest cm or adding an extra zero (recording to the nearest tenth of a millimetre) were common causes of lost credit.

(d) Most candidates recorded a second value for *L* and *x*.

Quality of data

(d) Most candidates found that, when *L* was reduced using the second strip, the value of *x* also reduced, gaining credit.

Display of calculation and reasoning

(a) (iv) Successful candidates noticed that the quantity *p* was found using the values of *m* and *L* so stated that the value of *p* was given to the same number of significant figures as the values of *m* and *L*. Candidates must state *m* and *L* (or the quantities relevant to the question) in their answer. Phrases such as 'raw data' or 'the values in the calculation' did not gain credit. A few candidates stated '3 s.f.' without any reasoning and this also did not gain credit.

(b) (iii) The calculation of *C* was successfully done by those candidates who correctly substituted their *M* value rather than the *m* value and understood how to interpret the brackets.

(e) (i) Most candidates were able to successfully rearrange the equation and calculate $k = x / C$ correctly for both experiments, although some candidates misunderstood how to rearrange and used $k = C / x$. Successful candidates gave their answers to 2 or 3 s.f. Some candidates rounded their answers to one significant figure so that both *k* values were identical, and this did not gain credit. Attempts to use metres and kg were common but often led to arithmetical errors.

Drawing conclusions

(e) (ii) Successful candidates had three steps in their arguments. They stated a percentage uncertainty that they thought was a sensible limit for the percentage uncertainty of this particular experiment such as 5% or 20% or the percentage uncertainty found in **(e)(iii)**, they calculated the percentage difference between their values of *k*, and they then compared the percentage difference with the percentage uncertainty and decided whether or not the relationship was supported. If the percentage difference between the two *k* values was less than the stated criterion, then the successful answers stated the relationship was supported. Candidates should understand that if the value of the percentage difference is greater than the value of the percentage uncertainty stated as the criterion, then the relationship is not supported and the candidate should state this e.g. "the relationship is not supported".

Estimating uncertainties

(c) (iii) Most candidates were familiar with the equation for calculating percentage uncertainty, though few made a realistic estimate of the absolute uncertainty in *x* of 2 mm – 5 mm. Many candidates stated the uncertainty as 1 mm or 0.5 mm.

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 it is difficult to judge to the centre of the mass, and the rule cannot actually touch the wooden strip or the balance would be disturbed. Realising these difficulties, successful candidates recorded repeat measurements of *x*. When repeat readings were taken the absolute uncertainty could be calculated as half the range of the repeated values, but not the full range. The half-range calculation needed to be shown so that it was clear how the estimate of absolute uncertainty has been produced.

Evaluation

(f) Successful candidates thought about difficulties while performing the experiment and made useful suggestions in **(f)**.

Good answers suggested detailed limitations and improvements specific to this balancing experiment. The best answers made specific points about where the major challenges were in the accurate measurement of *x* and the accurate positioning of the mass. Candidates were presented with a strip that would only be in balance for a short time and was very easy to displace while measuring *x*. One challenge was to measure *x* accurately. A suggestion of changing the strip for a rule was not credited, but the suggestion of adding a scale to the strip was made by stronger candidates.

Some candidates were able to state that two readings were not enough to draw a conclusion. As a solution, many candidates gained credit for suggesting taking more readings and plotting a graph. Candidates often stated that 'the measurement of *x* was difficult', but on its own this statement is not enough. An appropriate reason for the difficulty was needed. Similarly a statement such as 'it was difficult to balance the strip' was not enough, and candidates needed to add a reason such as 'because the pivot moved'. It was not sufficient to state that the strip was difficult to balance without giving a reason. The key to success in this section is for candidates to identify genuine problems associated with setting up this experiment. The three areas to consider here were balancing, mass position and obtaining accurate readings for *x*.

Candidates can improve their answers by stating the method used for each improvement. In doing this candidates should look at how each improvement helps and improves this particular experiment.

Credit is not given for suggestions of standard laboratory technique that could be carried out in the original experiment, such as repeating measurements or avoiding parallax errors. Vague or generic answers such as 'systematic error' or 'use an assistant' are not given credit.

PHYSICS

Paper 9702/32
Advanced Practical Skills 2

Key Messages

- Candidates should be reminded that they should always plot all of their tabulated readings on the graph in **Question 1**. If some of the readings do not fit on the graph grid, then a different scale should be chosen.
- Many candidates find it difficult to choose scales that make good use of the graph grid. The aim should be to occupy the majority of the graph grid. If less than half of the grid is occupied in one direction, the range of the corresponding axis can be halved to make better use of the grid.
- When deciding whether the relationship in **Question 2** is true, candidates should be encouraged to make a quantitative comparison and then make a precise statement consistent with their comparison. A vague phrase such as "within experimental accuracy" is not sufficient.
- 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. Candidates should be encouraged to write about four different problems and consequently four different solutions to address these problems, and should not try to state four solutions to the same problem.

General Comments

Centres generally did not have any difficulties in providing the equipment required for use by the 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 when marking. 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 help should **not** be given with the recording of results, graphical work or analysis.

Centres are reminded of the importance of following the Confidential Instructions exactly, using the materials and equipment specified. No 'extra' equipment should be available to the candidates. In some cases this may disadvantage candidates.

Nearly all candidates had time to complete both questions, and results and analysis were generally clearly presented. Very few candidates asked for help with using the apparatus. The standard shown in calculations was very good, and usually included accurate rounding of answers.

Some candidates gave answers from previous papers in the evaluation section of **Question 2**. These should not be included unless they are relevant to this particular experiment.

Comments on Specific Questions

Question 1

In this question, candidates investigated the supporting forces on a beam under various loads.

Successful collection of data

(c) Most candidates were able to record initial values of h and x in the expected range.

(d) Most candidates recorded six or more different values for h and x. In most cases, the x values showed the expected trend (increasing as h decreased). For a few candidates the value of x hardly changed, suggesting that the heights of both bosses had been changed when levelling the beam, instead of just boss A.

Range and distribution of values

(d) The best candidates were able to produce a range of x values that used the whole length of the beam. Candidates should be advised always to look at the range of values that their apparatus can provide, and try to use as much of the available range as possible.

Quality of data

(e) (i) Most candidates produced results with a good linear trend without much scatter, demonstrating good quality results.

Table

(d) Most tables were neat and well-organised. Stronger candidates used headings with suitable units where appropriate, with clear separation from their quantity. In a few cases the quantity x/h was mistakenly given a unit, usually cm.

Values for h and x were measured using a metre rule, and most candidates correctly recorded all their values to the nearest millimetre. Some candidates lost credit because they added a meaningless zero to each of their measurements and so did not record their results to the precision of the metre rule.

Calculated values of x/h were nearly always accurate, with incorrect rounding only in very few cases.

Stronger candidates knew how many significant figures to use for their calculated values of x/h. For example $x = 8.0$ cm and $h = 62.3$ cm could lead to either $x/h = 0.13$ or $x/h = 0.128$.

Graph

(e) (i) Good graphs showed simple, clearly labelled scales with all points from the table clearly and accurately plotted using small crosses. Where dots were used they were sometimes too large (over 1 mm in diameter), so that the intended position was not clear.

There were several cases of awkward scales, the most common error being one large square representing a value of 0.03. These scales making plotting and reading more difficult, and mistakes more likely. Some scales were very compressed, so that only a small part of the grid was used.

(ii) Not all of the drawn lines were the lines of best fit. In some cases the line was too far from one or more points, and in others the line was drawn to join the first and last points regardless of the distribution of the other points. There should always be a balanced distribution of points either side of the line along the entire length.

Interpretation of graph

(e) (iii) Nearly all candidates knew how to calculate the gradient of their line using coordinates from two points, though in a few cases the points were chosen from the table and did not lie on the drawn line of best fit.

Most candidates whose x/h axis started at zero read the intercept directly from their graph. Where it did not start at zero, weaker candidates often made the mistake of reading the intercept from the x/h axis instead of calculating a correct value using $y = mx + c$.

Drawing conclusions

(f) The majority of candidates inspected the equation and correctly equated *a* with the gradient value and *b* with the intercept value. Identifying the correct units for these constants was more difficult, and in many cases the units were omitted.

Question 2

This experiment investigated the surface tension force on a wire loop.

Successful collection of data

(a) (ii) Candidates were required to find the diameter of a wire loop and state the value in centimetres. The only measuring instrument available was a 30 cm ruler, so the measured value of *D* could only be made to the nearest 0.1 cm. Many candidates gave their values to an incorrect precision of 0.01 cm.

Stronger candidates recognised that the loop may not have been circular, so they took several measurements and averaged them.

(d) The values of r_1 and r_2 were read directly from the ruler, so stronger candidates gave them to the nearest 0.1 cm. Some weaker candidates added an extra zero, and others omitted the unit.

(e) Nearly all candidates repeated the experiment using the second loop which had a different diameter. In most cases the expected trend was found, i.e. the difference between r_1 and r_2 was greater when the loop diameter was greater.

Display of calculation and reasoning

(a) (iv) The calculation of the loop circumference *C* was done well, with only a few candidates omitting a correct unit.

(b) The majority of candidates knew that the number of significant figures given for *C* should be based on the raw data used in its calculation, i.e. their measurements of *D*. However, many candidates also mistakenly considered the constant π as raw data, even though its value does not have a fixed number of significant figures.

(f) (i) Most candidates successfully calculated two values for the constant *k*. A few candidates made mistakes when rearranging the equation or when transferring values into the equation, and a small number rounded their *k* values to 1 significant figure.

Drawing conclusions

(f) (ii) There were many good answers here, with clearly reasoned discussion based on the two *k* values. Some looked at the relative difference between the two values (i.e. the percentage difference) and compared it with the variation that could reasonably be expected for this experiment, such as 20%. Some applied their chosen percentage variation to each *k* value and then looked for overlap. Weaker answers discussed only whether the difference between *k* values was ‘large’ or ‘small’.

Estimating uncertainties

(a) (iii) Although the loop diameter *D* was measured to the nearest millimetre, the loop itself was not a perfect circle, so there was an uncertainty of between 2 and 5 mm in its value. Many candidates did not take this into account and simply used the 1 mm precision of their measuring instrument. Stronger candidates used an uncertainty greater than 1 mm, or alternatively used half the range of their repeated measurements of diameter.

Evaluation

(g) Most candidates made a good attempt at evaluating the experiment. Many candidates were credited for the general criticism that the validity of the equation could not be judged from only two values of *k*. More tests were needed using different loop diameters, followed by more comparisons.

Many candidates talked about some of the difficulties listed in the mark scheme, and good answers included reference to both the measurement and the difficulty, e.g. "the loop touched the beaker wall, and this may have affected the value of r_2".

For measuring an instantaneous value (such as r_2) the idea of a video recording is often suggested. For this it is important to make clear that the means of measurement (the ruler scale) is included in the frame.

Many candidates suggested the use of 'better' equipment or computers/data loggers/sensors without describing how such equipment would be used. Credit is not given for suggestions of standard laboratory technique that could be carried out in the original experiment, such as repeating measurements or avoiding parallax errors. Vague or generic answers such as 'systematic error' or 'use an assistant' are not given credit.

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.

PHYSICS

Paper 9702/33
Advanced Practical Skills 1

Key Messages

- Candidates should be reminded that they should always plot all of their tabulated readings on the graph in **Question 1**. If some of the readings do not fit on the graph grid, then a different scale should be chosen.

- Many candidates find it difficult to choose scales that make good use of the graph grid. The aim should be to occupy the majority of the graph grid. If less than half of the grid is occupied in one direction, the range of the corresponding axis can be halved to make better use of the grid.

- When deciding whether the relationship in **Question 2** is true, candidates should be encouraged to make a quantitative comparison and then make a precise statement consistent with their comparison. A vague phrase such as "within experimental accuracy" is not sufficient.

- 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. Candidates should be encouraged to write about four different problems and consequently four different solutions to address these problems, and should not try to state four solutions to the same problem.

General Comments

Centres generally did not have any difficulties in providing the equipment required for use by the 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 when marking. 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 help should **not** be given with the recording of results, graphical work or analysis.

Centres are reminded of the importance of following the Confidential Instructions exactly, using the materials and equipment specified. No 'extra' equipment should be available to the candidates. In some cases this may disadvantage candidates.

The general standard of the work done by the candidates was good, with many excellent scripts. Candidates did not seem to be short of time and both questions were attempted by almost all the candidates. They demonstrated good skills in the generation and handling of data but could improve by giving more thought to the analysis and evaluation of experiments.

Comments on Specific Questions

Question 1

In this question, candidates were asked to investigate how the position of a suspended card varies with the distribution of masses attached to it.

Successful collection of data

(b) (iv) The majority of candidates stated a value of *y* to within 0.5 cm of that expected (half the length of the card). Some candidates omitted the units.

(c) (ii) With the added slotted mass, most candidates correctly found that their new value of *y* was larger than that found in **(b)(iv)**.

(d) Most candidates were able to collect six sets of values of *m* and *y* without any assistance from the Supervisor. If candidates choose to record more than the prescribed six sets of values, it is important that all the extra points are plotted on the graph.

Range and distribution of values

(d) Many candidates did not extend their range of *m* values to include *m* = 0 g and *m* = 50 g or 60 g. Many candidates did not include *m* = 0 g despite being asked to include their results from **(b)**.

Quality of data

(e) (i) Most candidates were awarded credit for the quality of their data. Some candidates lost credit because their graphs were based on incorrect calculations of *y*(*C* + *m*).

Table

(d) Most candidates were awarded credit for using the correct column headings in their tables, giving both the quantity recorded 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 *y*(*C* + *m*), omitted the separating mark or recorded the units for *y*(*C* + *m*) as cm^2 g, g^2 m, 2 cm g, (g + g) cm or cm / g rather than cm g. Some candidates either omitted the mass column or the *y*(*C* + *m*) column making plotting the graph difficult.

Many candidates recorded their raw values for *y* to the nearest 0.1 cm, gaining credit. Some candidates incorrectly stated their *y* values to the nearest cm or presented trailing zeros to a greater precision than 1 mm when the measuring instrument provided (a ruler) can be read only to the nearest mm.

Many candidates calculated values for *y*(*C* + *m*) correctly, though a few rounded their answers incorrectly.

Some candidates recorded their calculated values for *y*(*C* + *m*) to an appropriate number of significant figures. Some candidates recorded their values to an inflated number of significant figures, sometimes up to seven significant figures when the mass was stated to two significant figures. It is expected that candidates record their calculated values to either the same number, or one more than, the least number of significant figures used in the raw readings of *y*, *C* and *m*.

Graph

(e) (i) The size of the graph axes chosen was generally good so that the plotted points occupied greater than half the graph grid available. Many candidates drew awkward scales on the *y*-axis (commonly multiples of three) and could not be awarded credit for the axes. This often also led to the loss of credit for plotting or for incorrect read-offs for the gradient and intercept because the scale was difficult to use correctly. Some candidates incorrectly placed their top point on the top line and their bottom point on the bottom line and divided the scale accordingly, which gave a very awkward scale.

Many candidates gained credit for plotting their tabulated readings correctly. Some candidates plotted *y* against *m* or (*C* + *m*) against *m* which was not asked for. A few candidates labelled the axes *y*(*C* + *m*) when in fact the values plotted were other combinations of *y*, *C* and *m*. If a point seems anomalous, candidates should repeat the measurement to check that an error in recording the 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 grid 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.

(ii) Some candidates were able to draw carefully considered lines of best fit, but others joined 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 along the entire length. Many lines needed rotation to get a better fit, or an anomalous point needed to be identified to justify the line drawn. Some candidates lost credit for lines that were kinked in the middle (candidates used too small a ruler), by drawing a double line (broken pencil tip) or by drawing freehand lines without the aid of a ruler.

Interpretation of graph

(e) (iii) Many candidates used a suitably large triangle to calculate the gradient, gaining credit for correct read-offs, and substituted into $\Delta y/\Delta x$ to find the gradient. Other candidates needed to check that the read-offs used were within half a small square of the line of best fit, show clearly the substitution into $\Delta y/\Delta x$ (not $\Delta x/\Delta y$), and check that the triangle for calculating the gradient is large enough (the hypotenuse should be greater than half the length of the line drawn).

Many candidates were able to correctly read off the *y*-intercept at $x = 0$ directly from the graph.

Many candidates correctly substituted a read-off into $y = mx + c$ to determine the *y*-intercept. Others needed to check that the point chosen was actually on the line of best fit and not just a point from the table.

Drawing conclusions

(f) Most candidates recognised that *A* was equal to the value of the gradient and *B* was equal to the twice the value of the intercept divided by the gradient. A few candidates confused *m*, the gradient in $y = mx + c$ with the mass *m*, which is the *x* variable. A few candidates tried to calculate *A* and *B* by first substituting values into the given equation and then solving simultaneous equations, or by repeating the calculations already completed in **(e)(iii)**. No credit is given for this as the question specifically asks for the answers in **(e)(iii)** to be used to determine *A* and *B*.

The majority of candidates recorded the correct units for *A* (cm or m) and *B* (g or kg) correctly. Others stated incorrect units or omitted the units for *A* and *B*.

Question 2

In this question, candidates were required to investigate the motion of a small container in water.

Successful collection of data

(a) (i) Some candidates recorded a value for *d* in the range 10.0 mm to 25.0 mm and for *D* in the range 20.0 mm to 40.0 mm with a correct unit. Many candidates recorded values out of range, possibly because of difficulty using the calipers. Many candidates stated the precision inconsistently between *d* and *D*. Candidates were expected to state their value to the smallest reading on the calipers e.g. $D = 3.55$ cm.

(ii) Many candidates recorded a value of *h* with a consistent unit.

(d) (ii) Most candidates recorded a value of *t* with a unit. A minority of candidates omitted the unit or misread the stopwatch and recorded 0.0001 s or 0.01 s instead of 1 s, or 83 s instead of 0.83 s. Some candidates did not record repeat readings either here or in **(e)**.

(e) Most candidates recorded second values for *x* and *t*.

Quality of data

(e) Most candidates recorded values for *t* which were smaller for the container with three marbles.

Display of calculation and reasoning

(b) (iii) Many candidates correctly calculated *x*.

(c) Some candidates justified the number of significant figures they had given for the value of *x* with reference to the number of significant figures used in *d*, *D* and *h*. Others referred to two of the raw values without mentioning the third. Reference to just the 'raw data' is not sufficient here and did not gain credit. A few candidates incorrectly made reference to the number of decimal places. The justification for one significant figure because *n* is an integer did not gain credit.

(f) (i) The majority of candidates were able to calculate *k* for the two sets of data, showing their working clearly. Many candidates rounded both values to 1 significant figure to compare *k* values which is not sufficient. A minority of candidates incorrectly rearranged the equation to calculate *k*.

Drawing conclusions

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

Estimating uncertainties

(a) (iii) Most candidates were familiar with the equation for calculating percentage uncertainty, though some made too large an estimate of the absolute uncertainty in the value of *h*, typically 1 mm when the vernier scale can be read to the nearest 0.1 mm. The reading is static and straightforward so the uncertainty will not be as large as 1 mm. Some candidates repeated their readings and correctly gave the uncertainty in *d* as half the range. Some other candidates incorrectly used the range without halving it, or multiplied it by the number of repeat readings.

Evaluation

(f) Many candidates recognised that two sets of data were insufficient to draw a valid conclusion. Several candidates identified the time being too short so that the experimental uncertainty in the time measurement is high. Some candidates had difficulty using the correct terminology to explain that refraction caused difficulty in judging the end point.

Valid improvements included taking more readings and then plotting a suitable graph to test the suggested relationship. Many improvements could not be credited because they were not specific enough, e.g. automatic light sensor, pressure sensor or robotic arm release mechanism.

Many candidates suggested the use of 'better' equipment or computers/data loggers/sensors without describing how such equipment would be used. Credit is not given for suggestions of standard laboratory technique that could be carried out in the original experiment, such as repeating measurements or avoiding parallax errors in the starting position or measurement of *h* by looking at eye level. Vague or generic answers such as 'systematic error' or 'use an assistant' are not given credit.

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.

PHYSICS

Paper 9702/34
Advanced Practical Skills 2

Key Messages

- Candidates should be reminded that they should always plot all of their tabulated readings on the graph in **Question 1**. If some of the readings do not fit on the graph grid, then a different scale should be chosen.

- Many candidates find it difficult to choose scales that make good use of the graph grid. The aim should be to occupy the majority of the graph grid. If less than half of the grid is occupied in one direction, the range of the corresponding axis can be halved to make better use of the grid.

- When deciding whether the relationship in **Question 2** is true, candidates should be encouraged to make a quantitative comparison and then make a precise statement consistent with their comparison. A vague phrase such as “within experimental accuracy” is not sufficient.

- 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. Candidates should be encouraged to write about four different problems and consequently four different solutions to address these problems, and should not try to state four solutions to the same problem.

General Comments

There was no evidence that Centres had any difficulties in providing the equipment required for use by the candidates. A few Centres provided metre rules for Question 1 that were too flexible to oscillate as intended for larger values of *r*, and this was taken into account when the scripts from these Centres were marked. 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 help should **not** be given with the recording of results, graphical work or analysis.

The general standard of the work done by the candidates was good, with many excellent scripts. Candidates did not seem to be short of time and both questions were attempted by almost all the candidates. They demonstrated good skills in the generation and handling of data but could improve by giving more thought to the analysis and evaluation of experiments.

Comments on Specific Questions

Question 1

In this question, candidates were asked to investigate a metre rule rocking on a beaker.

Successful collection of data

(b) (i) Almost all candidates recorded a value for *r* in the range 28.0 cm – 32.0 cm. Some candidates lost credit because they omitted units.

(c) (ii) Most candidates were able to record a time *T* in the range 2.0 s – 4.0 s and the majority repeated their measurements, either by recording the time for several oscillations and dividing their answers by the number of oscillations, or by recording the times for a number of single oscillations and finding the average. Several candidates mis-read the stopwatch, recording times of 0.01 s or less. Some candidates recorded the time for only half a complete oscillation.

(d) Most candidates were able to collect six sets of values of r and T without any assistance from the Supervisor. A few candidates lost credit as their results did not show the correct trend (T should increase as r increases).

Range and distribution of values

(d) Some candidates made good use of the range of possible values of r, ensuring that the difference between the smallest and largest values was 30 cm or greater, but many candidates needed to extend the range of values of r chosen to make better use of the apparatus.

Quality of data

(e) (i) Most candidates were awarded credit for the quality of their data. A few candidates obtained an incorrect (negative) trend on their graph, or had calculated values of T^2 rather than T^3.

Table

(d) The best candidates made good use of the space available on the paper when drawing their tables, starting with the independent variable r followed by repeat values of the measured time nT for n oscillations. The next column would be the average value of T followed by the calculated values r^2 and T^3 in the last two columns, making the plotting of the graph easier.

Most candidates were awarded credit for using the correct column headings in their tables, giving both the quantity recorded and suitable units for each quantity, with the two separated by a solidus or with the units in brackets. Centres should note that a quantity and a unit separated by a comma is not accepted. Some candidates gave the units for r^2 as cm rather than cm^2, or the units for T^3 as s rather than s^3.

Most candidates recorded their values for r to the nearest 0.1 cm. Others only recorded their values for r to the nearest cm.

Most candidates recorded their calculated values for T^3 to the same number of significant figures as (or one more than) the number of significant figures for T. Most candidates calculated values for T^3 correctly, though a few lost credit because they rounded their answers incorrectly, or added an extra zero to their value.

Graph

(e) (i) Most candidates gained credit for drawing appropriate axes, with labels and sensible scales. A few candidates chose extremely awkward scales, making the correct plotting of points much more difficult. This often also led to the loss of credit for plotting or for incorrect read-offs for the gradient and intercept because the scale was difficult to use correctly. Some candidates drew non-linear scales and lost credit for the axes and the quality (which cannot be judged).

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 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 grid 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.

(ii) Some candidates were able to draw carefully considered lines of best fit, but others joined 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 along the entire length. Many lines needed rotation to get a better fit, or an anomalous point needed to be identified to justify the line drawn. Some candidates lost credit for lines that were kinked in the middle (candidates used too small a ruler), by drawing a double line (broken pencil tip) or by drawing freehand lines without the aid of a ruler.

Interpretation of graph

(e) (iii) Many candidates used a suitably large triangle to calculate the gradient, gaining credit for correct read-offs, and substituted into $\Delta y/\Delta x$ to find the gradient. Other candidates needed to check that the read-offs used were within half a small square of the line of best fit, show clearly the substitution into $\Delta y/\Delta x$ (not $\Delta x/\Delta y$), and check that the triangle for calculating the gradient is large enough (the hypotenuse should be greater than half the length of the line drawn).

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.

Many candidates correctly substituted a read-off into $y = mx + c$ to determine the *y*-intercept. Others needed to check that the point chosen was actually on the line of best fit and not just a point from the table.

Drawing conclusions

(f) Most candidates recognised that *a* was equal to the value of the gradient and *b* was equal to the value of the intercept calculated in **(e)(iii)**. A few candidates tried to calculate *a* and *b* by first substituting values into the given equation and then solving the simultaneous equations, or by repeating the calculations already completed in **(e)(iii)**. No credit is given for this as the question specifically asks for the answers in **(e)(iii)** to be used to determine *a* and *b*.

The majority of candidates recorded the correct units for *a* ($s^3\,cm^{-2}$ or $s^3\,m^{-2}$) and *b* (s^3). Others omitted the units for *a* or *b*.

Question 2

In this question, candidates were required to investigate how the optical properties of a lens depend on its shape.

Successful collection of data

(a) (ii) Most candidates recorded a value for *t* in the range 0.10 cm – 0.90 cm successfully, giving their answers to the nearest 0.01 cm. A few candidates gave their answer to the nearest millimetre, not taking into account the precision of the vernier callipers, and were not awarded credit.

Almost all candidates recorded a value for *D* in the range 3.0 cm – 6.0 cm and most recorded a value for *h* (the thickness of the lens at the edge) that was less than *t* (the thickness of the lens at the centre).

(c) (ii) Candidates generally recorded a value for *f* that was within the specified range of focal lengths (either 15.0 ± 2.0 cm or 30.0 ± 2.0 cm). Some Centres used lenses with focal lengths different from those specified in the Confidential Instructions. This was acceptable but reinforces the importance of making such changes clear in the Supervisor's report so that Examiners can make appropriate adjustments to the mark scheme.

(d) Almost all candidates were able to record second values for *t*, *D* and *h*, and also went on to record a second value of *f*.

Quality of data

(e) (i) The values of *R* and *f* should be almost exactly the same, so that $k = 1$. Some candidates obtained values that were in the range 0.5 – 1.5 and were awarded credit. Others either carried forward an incorrect value of *t* or *h* into the calculation for *R*, or calculated *R* incorrectly, or measured *f* incorrectly.

Display of calculation and reasoning

(b) Almost all candidates were able to calculate *R* correctly, but many candidates recorded their value of *R* to too great a number of significant figures.

(e) (i) The great majority of candidates were able to calculate *k* correctly for the two sets of data, showing their working clearly. A few candidates calculated *f* / *R* and were not awarded credit.

Drawing conclusions

(e) (ii) Most candidates calculated the percentage difference between their two values of *k*, and then tested it against a specified percentage uncertainty, either taken from **(c)(iii)** or estimated themselves (usually 20%). Some candidates gave answers such as 'the difference in the two *k* values is very large/quite small' which is insufficient to be awarded credit. A numerical percentage comparison is required.

Estimating uncertainties

(c) (iii) Most candidates were familiar with the equation for calculating percentage uncertainty, though many made too small an estimate of the absolute uncertainty in the focal length. Such estimates should take into account the nature of the measurement itself as well as the precision of the instrument being used.

Evaluation

(f) Many candidates recognised that two sets of data were insufficient to draw a valid conclusion. Several candidates identified the measurement of *h* as a possible source of error, but without explaining why e.g. by stating that *h* was small so that there was a large uncertainty in its measurement. Several candidates stated that it was difficult to hold the lens steady in the hand but they needed to link this explicitly to error in the measurement of the focal length *f*.

Many candidates correctly identified the difficulty of judging exactly when the image on the screen was in sharp focus.

Valid improvements included taking more readings (for lenses of different focal lengths) and then plotting a suitable graph to test the suggested relationship, and using a micrometer screw gauge to measure *h*. Many candidates suggested using a dark room (or just turning off the lights) or mounting the lens in a lens holder to keep it steady. Other good suggestions included using a more compact source of light such as an LED or using an optical bench.

Many candidates suggested the use of 'better' equipment or computers/data loggers/sensors without describing how such equipment would be used. Credit is not given for suggestions of standard laboratory technique that could be carried out in the original experiment, such as repeating measurements or avoiding parallax errors. Vague or generic answers such as 'systematic error' or 'use an assistant' are not given credit.

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.

PHYSICS

Paper 9702/35
Advanced Practical Skills 1

Key Messages

- Candidates should be reminded that they should always plot all of their tabulated readings on the graph in **Question 1**. If some of the readings do not fit on the graph grid, then a different scale should be chosen.
- Many candidates find it difficult to choose scales that make good use of the graph grid. The aim should be to occupy the majority of the graph grid. If less than half of the grid is occupied in one direction, the range of the corresponding axis can be halved to make better use of the grid.
- When deciding whether the relationship in **Question 2** is true, candidates should be encouraged to make a quantitative comparison and then make a precise statement consistent with their comparison. A vague phrase such as "within experimental accuracy" is not sufficient.
- 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. Candidates should be encouraged to write about four different problems and consequently four different solutions to address these problems, and should not try to state four solutions to the same problem.

General Comments

Centres generally did not have any difficulties in providing the equipment required for use by the 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 when marking. 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 help should **not** be given with the recording of results, graphical work or analysis.

The general standard of the work done by the candidates was good, with many excellent scripts. Candidates did not seem to be short of time and both questions were attempted by almost all the candidates. They demonstrated good skills in the generation and handling of data but can improve by giving more thought to the analysis and evaluation of the experiments.

Comments on Specific Questions

Question 1

In this question, candidates were asked to investigate how the voltage across components in a circuit varies as the resistance of the circuit is changed.

Successful collection of data

(a) (ii) The majority of candidates stated a value of x to the nearest millimetre with a correct unit. Some candidates omitted the unit.

(b) (ii) Most candidates stated values of V_1 and V_2 in range with a unit. Some candidates omitted the unit and some others included an inappropriate unit, e.g. 150 V instead of 150 mV.

(c) Most candidates were able to collect six sets of values of *x*, V_1 and V_2 without any assistance from the Supervisor. If candidates choose to record more than the prescribed six sets of values, it is important that all the extra points are plotted on the graph.

Range and distribution of values

(c) Many candidates did not extend their range of *x* values over at least 60.0 cm. Many candidates took six readings sequentially in 10.0 cm steps from 10.0 cm to 60.0 cm and did not gain credit for their range of readings.

Quality of data

(d) (i) Most candidates were awarded credit for the quality of their data. Those candidates who did not gain credit often rounded their calculated values to too few significant figures, which increased the scatter on the graph.

Table

(c) Most candidates were awarded credit for using the correct column headings in their tables, giving both the quantity recorded and suitable units for each quantity, with the two separated by a solidus, or the units in brackets. Many candidates correctly gave no units for V_2 / V_1. Some other candidates stated V_2/V_1 / V/V. This did not gain credit as the unit at the top of the column should reflect the unit of the combined quantity V_2/V_1.

Many candidates recorded their raw values for *V* to the nearest 0.001 V, gaining credit. Some candidates incorrectly stated their *V* values to the nearest 0.01 V or presented trailing zeros to a greater precision than 0.001 V when the voltmeter can read to the nearest 0.001 V.

Many candidates calculated values for V_2/V_1 correctly, though a few rounded their answers incorrectly.

Some candidates recorded their calculated values for V_2/V_1 to an appropriate number of significant figures. Some candidates recorded their values to an inflated number of significant figures. It is expected that candidates record their calculated values to either the same number as, or one more than, the least number of significant figures used in the raw readings of V_2 and V_1.

Graph

(d) (i) The size of the graph axes chosen was generally good so that the plotted points occupied greater than half the graph grid available. Many candidates drew awkward scales on the *y*-axis (commonly multiples of three) and could not be awarded credit for the axes. This often also led to the loss of credit for plotting or for incorrect read-offs for the gradient and intercept because the scale was difficult to use correctly. Some candidates incorrectly placed their top point on the top line and their bottom point on the bottom line and divided the scale accordingly, which gave a very awkward scale.

Many candidates gained credit for plotting their tabulated readings correctly. Some candidates plotted V_1/V_2 against *x* which was not required. If a point seems anomalous, candidates should repeat the measurement to check that an error in recording the 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 grid 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.

(ii) Some candidates were able to draw carefully considered lines of best fit, but others joined 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 along the entire length. Many lines needed rotation to get a better fit, or an anomalous point needed to be identified to justify the line drawn. Some candidates lost credit for lines that were kinked in the middle (candidates used too small a ruler), by drawing a double line (broken pencil tip) or by drawing freehand lines without the aid of a ruler.

Interpretation of graph

(d) (iii) Many candidates used a suitably large triangle to calculate the gradient, gaining credit for correct read-offs, and substituted into $\Delta y/\Delta x$ to find the gradient. Other candidates needed to check that the read-offs used were within half a small square of the line of best fit, show clearly the substitution into $\Delta y/\Delta x$ (not $\Delta x/\Delta y$), and check that the triangle for calculating the gradient is large enough (the hypotenuse should be greater than half the length of the line drawn).

Many candidates were able to correctly read off the *y*-intercept at $x = 0$ directly from the graph.

Many candidates correctly substituted a read-off into $y = mx + c$ to determine the *y*-intercept. Others needed to check that the point chosen was actually on the line of best fit and not just a point from the table.

Drawing conclusions

(e) Many candidates recognised that *A* was equal to 15 × gradient and *B* was equal to 10 / intercept from **(d)(iii)**. A few candidates tried to calculate *A* and *B* 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 *A* and *B*.

Many candidates recorded the correct units for *A* ($\Omega\,m^{-1}$) and *B* (Ω) correctly. Others stated incorrect units e.g. *B* in $\Omega\,m$ or omitted the units for *A* and *B*.

Question 2

In this question, candidates were required to investigate the motion of a metal bar.

Successful collection of data

(c) (i) Many candidates correctly recorded a value for θ to the nearest degree. Some candidates added trailing zeros. This precision is not justified because a protractor can only be read to a precision of one degree.

(d) (ii) Many candidates recorded and repeated values of T_1 in range and with a consistent unit. Some of the candidates misread the stopwatch and stated (e.g.) 80 s or 0.0080 s, which are out of range. Other candidates did not repeat their readings either here or in **(f)(ii)**, or omitted units.

(e) (ii) Most candidates recorded a value for T_2 in range and with a unit.

(f) (ii) Most candidates recorded second values for θ, T_1 and T_2.

Quality of data

(f) (ii) Many candidates recorded larger values for T_1 and smaller values for T_2 when the loops of string were closer together.

Display of calculation and reasoning

(c) (iii) Many candidates correctly calculated $\cos(\theta/2)$.

(g) (i) The majority of candidates were able to calculate *k* for the two sets of data, showing their working clearly. Some candidates rounded one or both values of *k* to just one significant figure which is not sufficient. A minority of candidates incorrectly rearranged the equation to calculate *k*.

(ii) Some candidates justified the number of significant figures they had given for the values of *k*, giving reference to the number of significant figures used in T_1, T_2 and θ. Others gave reference to two of the raw values without mentioning the third. Many candidates referred incorrectly to the number of significant figures used in cos(θ/2) rather than the number used in θ. Reference to just the 'raw data' is not sufficient. A few candidates incorrectly made reference to the number of decimal places.

Drawing conclusions

(g) (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 **(c)(ii)** or estimated themselves. Some candidates gave answers such as 'the difference in the two *k* values is very large/quite small' which is insufficient to be awarded credit. A numerical percentage comparison is required.

Estimating uncertainties

(c) (ii) Most candidates were familiar with the equation for calculating percentage uncertainty. Some candidates made too small an estimate of the absolute uncertainty in the value of θ, typically using 1°. This is insufficient as, although the protractor can be read to the nearest 1°, the reading is difficult and awkward to take as the rod is in the way. Some candidates repeated their readings and correctly gave the uncertainty in θ as half the range. Some other candidates incorrectly used the full range without halving it.

Evaluation

(h) Many candidates recognised that two sets of data were insufficient to draw a valid conclusion. Many candidates identified the angle as difficult to measure as the rod is in the way or the protractor is hand-held and so is not steady.

Valid improvements included taking more readings and then plotting a suitable graph to test the suggested relationship. Some improvements were not specific enough, e.g. use of a video without specifying the need to use a timer.

The key to this section is for candidates to identify genuine problems associated with setting up this experiment and in obtaining readings. For example, it was difficult to take the time as the oscillations were too few as they were damped after just a few oscillations. Candidates are encouraged to suggest detailed practical solutions that either improve technique or give more reliable data.

Many candidates suggested the use of 'better' equipment or computers/data loggers/sensors without describing how such equipment would be used. Credit is not given for suggestions of standard laboratory technique that could be carried out in the original experiment, such as repeating measurements or avoiding parallax errors. Vague or generic answers such as 'systematic error' or 'use an assistant' are not given credit.

PHYSICS

Paper 9702/41
A2 Structured Questions

Key Messages

- Some candidates quote formulae without giving a subject. It is not always possible for the Examiner to know what is intended by the candidate, especially when subsequent working is not wholly correct, and as a result it may not be possible to award credit. Candidates should be encouraged to show clearly the subject of all formulae used.

- Candidates are advised that they should show their working, including relevant explanation. It is particularly important to include words of explanation when the question contains the command word "show". The meaning of any symbols used should be stated.

- A key area for learning is to understand the underlying concepts behind the areas of physics tested on this paper. Questions with the command word "explain" require a detailed response that uses this underlying knowledge of physics. To be awarded full credit in these questions, a statement without explanation is not sufficient.

General Comments

The majority of candidates attempted parts of the whole examination paper showing they had sufficient time to complete their answers. Many candidates' responses showed that they would benefit from further preparation for ***Section B***. Some papers had significant omissions in the final four questions.

Candidates also found **Question 7** to be particularly difficult, and would benefit from further work on the principles and advantages of a.c. electrical distribution at high voltages.

It was noted that candidates found it difficult to state laws and quote definitions accurately. Some definitions were muddled with that for a different quantity, and some responses missed out key terms.

Comments on Specific Questions

Section A

Question 1

(a) This law was stated well but many candidates did not refer to point masses.

(b) The most common omission was the idea that the gravitational force provides the centripetal force. Weaker candidates just rearranged the expression given and a number of candidates lost credit because they did not use the symbols provided. Another common error was to start at $GM_N/r = v^2$ rather than first principles.

(c) The ratio of the two masses could be found relatively easily using the given equation, but instead many candidates worked out the masses of the planets. This was difficult as it required a lot of conversion from days to seconds and km to m. Non-SI values of mass were acceptable provided the candidate did not mistakenly label these as "kg". Candidates should be reminded that a ratio should always be given as a decimal number, not a fraction.

Question 2

(a) The most common mistake was to forget to mention atoms/molecules/particles of a system.

(b) (i) This was generally well calculated, but some candidates lost credit by rounding to 1 s.f. A small number of candidates used the change in pressure and temperature to correctly calculate the correct value. A smaller number spoiled their work by mistakenly using the difference in volume from C to A.

(ii) There were few problems here. Some candidates misread the scale on the graph.

(c) Few candidates correctly linked the change in volume to work done and the change in temperature to internal energy. Some candidates who considered the work done thought that the temperature would be increasing. The key point to realise was that work was done on the gas *and* it was cooling.

Question 3

(a) This definition was found to be quite difficult by a considerable number of candidates. Many candidates wrote about the energy needed to change 1 kg of a substance, which is mixing quantities and units. It is essential that candidates realise that they must use "unit mass" in their definitions. Also, the word "specific" is important: they must refer to unit mass, rather than just the energy needed to convert a substance from one state to another.

(b) (i) This was well done, but some candidates only divided by 5 or 60, not both. Some weak candidates multiplied and this did not give a sensible answer.

(ii) Many candidates used just one set of data to calculate *L* and ignored the energy gains from the surroundings. Some did use the second set as well and then averaged the two values. These approaches are not correct. Stronger candidates were able to use the difference in powers and the differences in masses to get the correct value for the latent heat, but their approach to **part 2** often showed that they did not understand how their method worked, as they were not able to find the rate of thermal energy gained from the surroundings.

Question 4

(a) (i) The idea of a driving oscillator was well understood but it was less often coupled to the fact that it would produce a frequency in the driven system.

(ii) When this was answered correctly, it was most often in terms of there being no external force acting.

(iii) This part of the question was often answered correctly. The idea of forced frequency being equal to natural frequency was well understood. Fewer candidates made the link to maximum amplitude.

(b) This is an example of a "state and explain" question. It was essential that the object vibrating was mentioned. Those who did this often then found it difficult to identify exactly why resonance was useful in that case. For example "microwave ovens" are not an example of resonance as there is no statement of what is resonating. The second mark was given for showing why this was useful.

(c) As in **(b)**, "bridges" (for example) are not an example of a situation where resonance should be avoided. "The vibration of bridges" is a better answer. The second mark was given for how to reduce the effect of resonance. Cars going over a bump in the road are not an example of resonance, as there is no forcing frequency.

Question 5

(a) There were many answers which stated that field strength is *V*/*d* without further comment. A few candidates gave correct expressions for *V* and *E* leading to this, and so gained the mark. Slightly more candidates mentioned that field strength was the gradient of the graph.

The calculation was much more successful. A small number of candidates did not include correct powers of ten for either or (more rarely) both quantities. Of those who used the gradient method, a significant number of results lay beyond the allowed range because the gradient had not been determined carefully.

(b) (i) There were many correct answers here.

(ii) Most candidates were successful here, but some weaker candidates did not correctly recall the formula for capacitance.

Question 6

(a) Many candidates responded with only one force for each situation. Candidates need to realise that a particle will have mass.

(b) Very few candidates determined the correct direction of the magnetic field. The calculation part of this question proved relatively straightforward.

(c) Very few candidates realised that the particle would be undergoing circular motion with a smaller radius of curvature. Candidates should be encouraged to take care with the drawing of diagrams.

Question 7

(a) The most common answer was the fact that the voltage can be changed “easily”, rather than efficiently.

(b) The idea of current being smaller was well understood, but many candidates did not also say that this could occur while the power transmitted remains the same. Likewise, the idea of power loss being smaller, or less heating occurring, was also popular but very few candidates related this to the cables or wires.

Question 8

(a) (i) Candidates who realised that the de Broglie equation was required then carried out the calculation with few problems. Some others attempted to use momentum = *mv* and used the mass of the electron. This could not be awarded credit. A tiny minority used the wrong wavelength.

(ii) Candidates who knew and used the correct expression answered this question well. Again, the mass of the electron appeared for those candidates who used the kinetic energy formula, and this could not be awarded credit.

(b) (i) Most candidates were able to use the formula provided. Some candidates substituted one wavelength instead of the change and some were unable to carry out the manipulation correctly to lead to the angle after the substitution.

(ii) This was a challenging question. If the collision is elastic and the photon has lost energy (because its wavelength has increased) then it must have given that energy to the electron. Very few candidates realised this. Some weaker candidates were unable to link the longer wavelength with a reduction in photon energy.

Question 9

(a) Radioactive decay is a nuclear process. A significant number of candidates did not make any reference to nuclei in their answers.

(b) Although many candidates received partial credit, many did not demonstrate a complete understanding of what happens when a radioisotope decays. A large number of candidates did not confine themselves to the symbols given and used a variety of others, which were often not defined.

(c) Stronger candidates were able to draw a reasonably convincing smooth curve hitting the appropriate points with sufficient accuracy. There were some straight lines and a larger number of curves with the wrong shape. A small number simply copied the curve given.

Section B

Question 10

(a) (i) Many candidates obtained the correct answer.

(ii) Many candidates did not understand what was happening in terms of comparing the inputs of this circuit. A common mistake was to confuse the output voltage from the amplifier with V_{OUT}, which were two different quantities in this circuit. The function of the diode was not well understood.

(b) (i) The output of this circuit being a square wave was well understood by some candidates. However a large number drew waves that just replicated the input voltage given.

(ii) Very few candidates were able to suggest an appropriate use for the circuit.

Question 11

(a) The key word in this question is "tube". Although candidates did give ways for the hardness of the beam to be controlled, they often did not explain this in terms of the anode voltage. Many of those who mentioned the anode voltage did not go on to explain how changing the anode voltage changed the hardness of the beam.

(b) (i) Most candidates were correct.

(ii) Few candidates included enough detail to be awarded full credit. Some candidates recognised that the two absorption coefficients were very similar, but were unable to take this any further. Other candidates thought that this was a big difference and that the blood would absorb all the X-rays, leaving none to be absorbed by the muscle.

Question 12

(a) There were some candidates who confused the words "information" and "device" and talked about antennae as receivers of information via a coaxial cable, for example, instead of the device that was receiving the information, such as a television.

(b) There were many correct responses to this question. A small number of candidates thought that information would travel faster, and some talked in terms of absolutes such as "no noise" or "no possibility of intercepting information". Common correct answers involved references to bandwidth, noise and attenuation.

(c) This was a difficult question and there were few correct answers. Candidates need to understand the idea of different areas of attenuation and apply them accurately if they wish to gain credit for this type of question.

Question 13

(a) This question proved to be very challenging and there were few correct answers. The two magnetic fields have distinct purposes and many candidates confused them in their answers.

(b) Many candidates carried out a successful calculation here. A small number of candidates rounded to 1.0 and some to 1. A minority confused frequency with energy and a smaller number rearranged the equation incorrectly.

PHYSICS

Paper 9702/42

A2 Structured Questions

Key Messages

- Some candidates quote formulae without giving a subject. It is not always possible for the Examiner to know what is intended by the candidate, especially when subsequent working is not wholly correct, and as a result it may not be possible to award credit. Candidates should be encouraged to show clearly the subject of all formulae used.
- Candidates are advised that they should show their working, including relevant explanation. It is particularly important to include words of explanation when the question contains the command word "show". The meaning of any symbols used should be stated.
- A key area for learning is to understand the underlying concepts behind the areas of physics tested on this paper. Questions with the command word "explain" require a detailed response that uses this underlying knowledge of physics. To be awarded full credit in these questions, a statement without explanation is not sufficient.

General Comments

Some candidates did not answer all parts of all questions. There was no evidence of a shortage of time for candidates to complete their answers.

Candidates should take particular care to check that their numerical answers are of a sensible order of magnitude. A gravitational force of several meganewton on the 2.5 kg mass in **Question 1(a)(i)1.**, for example, could be recognised as implausible. This would help the candidate to realise that an error has been made, which could then be investigated further.

Comments on Specific Questions

Section A

Question 1

(a) (i) 1. Generally, the correct expression was given. Frequently, the power-of-two for the radius was omitted, despite being correct in the general expression. Some candidates did not correctly convert from kilometres to metres.

2. A correct expression was seen in most scripts. Many candidates made errors similar to those in **part 1**.

(ii) The majority of candidates realised that the reading on the newton-meter would be the difference between the two answers in **(a)(i)**. A significant number either gave the answer calculated in **part 1** or calculated 2.50 g.

(b) There were very few correct responses except from the strongest candidates. Many candidates did not consider centripetal force and did not make any connection with the reasoning used in **(a)**. The majority of answers were based on either negligible gravitational force or the influence of other stars and planets.

Question 2

(a) This question was generally answered well.

(b) A common error was to calculate the square of the answer obtained in **(a)**. Some candidates made arithmetical errors or used an inappropriate number of significant figures.

(c) Many candidates did not understand the significance of this term in the context of kinetic theory. Division of the answer in **(b)** by $\sqrt{2}$ was a frequent mistake.

Question 3

(a) The definition was often given in terms of either "a substance" or "matter" or "a kilogram" rather than the energy required per/for unit mass. The condition that there must be constant temperature should be included.

(b) (i) This question was generally answered correctly but some discussed mass per unit time being constant, without any reference to the graph.

(ii) A correct expression linking specific latent heat to power was quoted in most scripts. In many answers, a single point on the line was used, rather than the gradient. Power-of-ten errors were common.

(iii) There were many correct answers based on "heat lost to the surroundings". Others made inappropriate reference to heat gained by the beaker or the apparatus. These items would remain at constant temperature.

Question 4

(a) This was generally answered correctly.

(b) (i) Candidates found this difficult and the correct phase angle was given in very few scripts.

(ii) In general, the relevant equation was known. Often, when substituting for angular frequency, ω was not squared in the calculation. Power-of-ten errors were common.

(iii) Many candidates were unable to link maximum kinetic energy to the data provided. Others gave different time periods for the two oscillations.

(c) Most candidates were able to draw a straight line with negative gradient through the origin. Some did not use data from **(b)** in order to fix the end-points of the line.

Question 5

(a) Many answers were incomplete as they did not specify *unit positive charge* being moved from infinity.

(b) (i) In general, this question was answered correctly in terms of the gradient of the line. Candidates should be advised that the expression $E = V/x$ is applicable only to uniform fields (and in this case V and x are not the co-ordinates of a point).

(ii) Many answers lacked sufficient detail, and contained only statements that the force decreases and then increases. It was expected that reference would be made to maximum force at $x = 0$, reducing to zero force at $x = 6$ cm and then increasing, but in the opposite direction. Some candidates stated that force would be proportional to the potential at a point.

(c) (i) This question was generally answered correctly.

(ii) 1. There were very few incorrect readings.

2. This question asked for an explanation. As a minimum, a recognisable equation indicating the energy changes and with standard symbols was expected. There were many correct solutions, but a significant number of these did not have an explanation. There was some confusion as to the use of specific charge, usually amongst those candidates who had not provided an initial equation as explanation.

Question 6

(a) Most answers were correct.

(b) (i) Many candidates found it difficult to show the correct direction.

(ii) 1. This calculation was generally carried out correctly.

2. Many candidates did not calculate the energy change of the photon but instead used the initial photon energy. Others considered the electron to be a photon and used an incorrect expression for kinetic energy.

(c) There were very few candidates who considered momentum in their answers. Many attempted to give an explanation in terms of loss of energy, despite the statement that the collision is elastic.

Question 7

(a) Many answers contained a statement of the laws of electromagnetic induction but with very little application to this specific situation. Most explained the production of an induced e.m.f., but few described this as being in the solenoid. Candidates found it difficult to explain the need to do work to move the magnet, and the reason for this.

(b) A significant number of candidates stated that the current in the primary coil would give rise to a flux in the core. Only the strongest candidates were then able to go on to state why an e.m.f. is induced in the secondary coil, regardless of any phase angle.

Question 8

(a) (i) Most candidates showed a correct conversion but a significant minority confused eV either with keV or with MeV.

(ii) Many answers were correct but a significant number of candidates did not take into consideration the efficiency of the process.

(b) (i) There was some confusion as to the number of days in 1.0 years. This is usually accepted to be 365 (to 3 significant figures). Some candidates used 360 days, perhaps because of confusion with angular degrees.

(ii) This calculation was found to be difficult. Using the decay constant in **(b)(i)** and the activity from **(a)(ii)**, it was expected that the number of nuclei would be calculated and hence the mass. Many candidates used the activity in **(a)(ii)** as the number of nuclei.

(c) Very few candidates related the initial and final powers to the equation for the exponential decay of a radioactive source. A large number of candidates attempted to answer this question using a linear relationship.

Section B

Question 9

(a) Stronger candidates were able to use the potential divider equation to find the potentials at A and at B. Many candidates attempted to determine a combined resistance and currents in various combinations of resistors.

(b) (i) Candidates found it difficult to complete the diagram for the inverting amplifier. In those circuits that were correct, the positive terminal of the voltmeter was usually shown correctly.

(ii) Many candidates did not make it clear that the ratio of the feedback resistance to the input resistance is 40.

Question 10

(a) In general, this definition was stated correctly. Some referred to "speed" without making it clear to what the speed refers. A very small number of candidates gave the speed as the speed of light.

(b)(i) There were many correct answers. Some did not correctly convert the wavelength to the unit of mm.

(ii) The calculations of the ratio were frequently not identified in terms of the media involved. This meant that any subsequent comment had little meaning. Frequently, the explanation was given in very loose terms, such as "the waves can get through", rather than discussing the intensities of the transmitted and reflected beams. A significant minority did not carry out any calculation.

Question 11

(a) (i) A significant minority suggested that component A would be an insulator, rather than a metal.

(ii) There were many correct suggestions. Candidates should carefully distinguish between the *reduction* and the *prevention* of factors such as noise.

(b)(i) The great majority gave a correct response. Some referred loosely to either *strength* or *signal* when a more precise word should be used.

(ii) Generally, candidates did not appreciate that the purpose of the log scale is to compress a large range of values into a more manageable scale.

(c) Very few candidates included a negative sign in order to account for an attenuation. Some showed clearly that the reciprocal of the gain was required and thus obtained the correct answer. Others effectively determined an attenuation greater than unity but did not notice that this was unrealistic. Candidates should be encouraged to carry out a check on their answers, which may help identify problems in the working.

Question 12

In general, this question was answered well by those candidates who had prepared themselves for topics included in Section B of the syllabus.

PHYSICS

Paper 9702/43
A2 Structured Questions

Key Messages

- Some candidates quote formulae without giving a subject. It is not always possible for the Examiner to know what is intended by the candidate, especially when subsequent working is not wholly correct, and as a result it may not be possible to award credit. Candidates should be encouraged to show clearly the subject of all formulae used.

- Candidates are advised that they should show their working, including relevant explanation. It is particularly important to include words of explanation when the question contains the command word "show". The meaning of any symbols used should be stated.

- A key area for learning is to understand the underlying concepts behind the areas of physics tested on this paper. Questions with the command word "explain" require a detailed response that uses this underlying knowledge of physics. To be awarded full credit in these questions, a statement without explanation is not sufficient.

General Comments

The majority of candidates attempted parts of the whole examination paper showing they had sufficient time to complete their answers. Many candidates' responses showed that they would benefit from further preparation for ***Section B***. Some papers had significant omissions in the final four questions.

Candidates also found **Question 7** to be particularly difficult, and would benefit from further work on the principles and advantages of a.c. electrical distribution at high voltages.

It was noted that candidates found it difficult to state laws and quote definitions accurately. Some definitions were muddled with that for a different quantity, and some responses missed out key terms.

Comments on Specific Questions

Section A

Question 1

(a) This law was stated well but many candidates did not refer to point masses.

(b) The most common omission was the idea that the gravitational force provides the centripetal force. Weaker candidates just rearranged the expression given and a number of candidates lost credit because they did not use the symbols provided. Another common error was to start at $GM_N/r = v^2$ rather than first principles.

(c) The ratio of the two masses could be found relatively easily using the given equation, but instead many candidates worked out the masses of the planets. This was difficult as it required a lot of conversion from days to seconds and km to m. Non-SI values of mass were acceptable provided the candidate did not mistakenly label these as "kg". Candidates should be reminded that a ratio should always be given as a decimal number, not a fraction.

Question 2

(a) The most common mistake was to forget to mention atoms/molecules/particles of a system.

(b) (i) This was generally well calculated, but some candidates lost credit by rounding to 1 s.f. A small number of candidates used the change in pressure and temperature to correctly calculate the correct value. A smaller number spoiled their work by mistakenly using the difference in volume from C to A.

(ii) There were few problems here. Some candidates misread the scale on the graph.

(c) Few candidates correctly linked the change in volume to work done and the change in temperature to internal energy. Some candidates who considered the work done thought that the temperature would be increasing. The key point to realise was that work was done on the gas *and* it was cooling.

Question 3

(a) This definition was found to be quite difficult by a considerable number of candidates. Many candidates wrote about the energy needed to change 1 kg of a substance, which is mixing quantities and units. It is essential that candidates realise that they must use "unit mass" in their definitions. Also, the word "specific" is important: they must refer to unit mass, rather than just the energy needed to convert a substance from one state to another.

(b) (i) This was well done, but some candidates only divided by 5 or 60, not both. Some weak candidates multiplied and this did not give a sensible answer.

(ii) Many candidates used just one set of data to calculate *L* and ignored the energy gains from the surroundings. Some did use the second set as well and then averaged the two values. These approaches are not correct. Stronger candidates were able to use the difference in powers and the differences in masses to get the correct value for the latent heat, but their approach to **part 2** often showed that they did not understand how their method worked, as they were not able to find the rate of thermal energy gained from the surroundings.

Question 4

(a) (i) The idea of a driving oscillator was well understood but it was less often coupled to the fact that it would produce a frequency in the driven system.

(ii) When this was answered correctly, it was most often in terms of there being no external force acting.

(iii) This part of the question was often answered correctly. The idea of forced frequency being equal to natural frequency was well understood. Fewer candidates made the link to maximum amplitude.

(b) This is an example of a "state and explain" question. It was essential that the object vibrating was mentioned. Those who did this often then found it difficult to identify exactly why resonance was useful in that case. For example "microwave ovens" are not an example of resonance as there is no statement of what is resonating. The second mark was given for showing why this was useful.

(c) As in **(b)**, "bridges" (for example) are not an example of a situation where resonance should be avoided. "The vibration of bridges" is a better answer. The second mark was given for how to reduce the effect of resonance. Cars going over a bump in the road are not an example of resonance, as there is no forcing frequency.

Question 5

(a) There were many answers which stated that field strength is V/d without further comment. A few candidates gave correct expressions for V and E leading to this, and so gained the mark. Slightly more candidates mentioned that field strength was the gradient of the graph.

The calculation was much more successful. A small number of candidates did not include correct powers of ten for either or (more rarely) both quantities. Of those who used the gradient method, a significant number of results lay beyond the allowed range because the gradient had not been determined carefully.

(b) (i) There were many correct answers here.

(ii) Most candidates were successful here, but some weaker candidates did not correctly recall the formula for capacitance.

Question 6

(a) Many candidates responded with only one force for each situation. Candidates need to realise that a particle will have mass.

(b) Very few candidates determined the correct direction of the magnetic field. The calculation part of this question proved relatively straightforward.

(c) Very few candidates realised that the particle would be undergoing circular motion with a smaller radius of curvature. Candidates should be encouraged to take care with the drawing of diagrams.

Question 7

(a) The most common answer was the fact that the voltage can be changed "easily", rather than efficiently.

(b) The idea of current being smaller was well understood, but many candidates did not also say that this could occur while the power transmitted remains the same. Likewise, the idea of power loss being smaller, or less heating occurring, was also popular but very few candidates related this to the cables or wires.

Question 8

(a) (i) Candidates who realised that the de Broglie equation was required then carried out the calculation with few problems. Some others attempted to use momentum = *mv* and used the mass of the electron. This could not be awarded credit. A tiny minority used the wrong wavelength.

(ii) Candidates who knew and used the correct expression answered this question well. Again, the mass of the electron appeared for those candidates who used the kinetic energy formula, and this could not be awarded credit.

(b) (i) Most candidates were able to use the formula provided. Some candidates substituted one wavelength instead of the change and some were unable to carry out the manipulation correctly to lead to the angle after the substitution.

(ii) This was a challenging question. If the collision is elastic and the photon has lost energy (because its wavelength has increased) then it must have given that energy to the electron. Very few candidates realised this. Some weaker candidates were unable to link the longer wavelength with a reduction in photon energy.

Question 9

(a) Radioactive decay is a nuclear process. A significant number of candidates did not make any reference to nuclei in their answers.

(b) Although many candidates received partial credit, many did not demonstrate a complete understanding of what happens when a radioisotope decays. A large number of candidates did not confine themselves to the symbols given and used a variety of others, which were often not defined.

(c) Stronger candidates were able to draw a reasonably convincing smooth curve hitting the appropriate points with sufficient accuracy. There were some straight lines and a larger number of curves with the wrong shape. A small number simply copied the curve given.

Section B

Question 10

(a) (i) Many candidates obtained the correct answer.

(ii) Many candidates did not understand what was happening in terms of comparing the inputs of this circuit. A common mistake was to confuse the output voltage from the amplifier with V_{OUT}, which were two different quantities in this circuit. The function of the diode was not well understood.

(b) (i) The output of this circuit being a square wave was well understood by some candidates. However a large number drew waves that just replicated the input voltage given.

(ii) Very few candidates were able to suggest an appropriate use for the circuit.

Question 11

(a) The key word in this question is "tube". Although candidates did give ways for the hardness of the beam to be controlled, they often did not explain this in terms of the anode voltage. Many of those who mentioned the anode voltage did not go on to explain how changing the anode voltage changed the hardness of the beam.

(b) (i) Most candidates were correct.

(ii) Few candidates included enough detail to be awarded full credit. Some candidates recognised that the two absorption coefficients were very similar, but were unable to take this any further. Other candidates thought that this was a big difference and that the blood would absorb all the X-rays, leaving none to be absorbed by the muscle.

Question 12

(a) There were some candidates who confused the words "information" and "device" and talked about antennae as receivers of information via a coaxial cable, for example, instead of the device that was receiving the information, such as a television.

(b) There were many correct responses to this question. A small number of candidates thought that information would travel faster, and some talked in terms of absolutes such as "no noise" or "no possibility of intercepting information". Common correct answers involved references to bandwidth, noise and attenuation.

(c) This was a difficult question and there were few correct answers. Candidates need to understand the idea of different areas of attenuation and apply them accurately if they wish to gain credit for this type of question.

Question 13

(a) This question proved to be very challenging and there were few correct answers. The two magnetic fields have distinct purposes and many candidates confused them in their answers.

(b) Many candidates carried out a successful calculation here. A small number of candidates rounded to 1.0 and some to 1. A minority confused frequency with energy and a smaller number rearranged the equation incorrectly.

PHYSICS

Paper 9702/51
Planning, Analysis and Evaluation

Key Messages

- In **Question 1**, candidates' responses should include detailed explanations of experimental procedures.
- 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 was an unfamiliar laboratory experiment. Candidates were required to plan an experiment using a vibrator at a given potential difference to determine the maximum frequency of an oscillating metal plate at which a small mass remains in contact with the plate. Many candidates describing the method should have included more detail. Diagrams can be improved, particularly in the drawing of workable electrical circuits. The graphical analysis was generally understood and done well. Many candidates did not provide enough additional detail to receive credit; for example, many candidates could not describe the use of an oscilloscope to measure frequency.

Question 2 required the candidates to plot a log–log graph. Many candidates made rounding errors in the table of results and/or quoted values of log *P* to too few decimal places. The plotting of points and error bars and the drawing of straight lines were generally done well. The reading of co-ordinates for the calculation of the gradient and calculation of the intercept was also generally good. Some errors were made in the analysis part at the end of the question.

It is clear that the stronger candidates 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 practical support booklets which are available from the Teacher Support Site.

Comments on Specific Questions

Question 1

Candidates were required to plan an experiment using a vibrator at a given potential difference to determine the maximum frequency of an oscillating metal plate at which a small mass remains in contact with the plate. Candidates also needed to explain how to obtain an expression for the constant *k* – this should be explained using graphical analysis.

Most candidates correctly identified the independent and dependent variables. Many candidates did not receive further credit for defining the experiment. Candidates needed to explain that they would adjust the frequency until the small mass just left the plate for a given alternating potential difference or, alternatively, candidates needed to explain that they would adjust the alternating potential difference until the small mass just left the plate for a given frequency.

Further credit is then available for controlling variables: candidates should indicate how a fair test could be carried out by keeping appropriate variables constant. Candidates should explicitly identify the variables that need to be kept constant; "controlled" is not an acceptable alternative to the word "constant". Examiners were expecting a reference to be made to keeping the position of the mass 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 vibrator connected with two leads to a signal generator. Labelled diagrams should be realistic in showing the laboratory setup. It was also expected that there would be a voltmeter or cathode-ray oscilloscope correctly positioned to determine the alternating potential difference. The circuit must be workable. In any electric circuit, voltmeters and cathode-ray oscilloscopes must be connected in parallel with the component across which the potential difference is to be measured.

A mark was available for measuring the frequency from the cathode-ray oscilloscope or signal generator. There were two additional detail marks available for explaining how to determine the period from a cathode-ray oscilloscope and hence the frequency. Using a stop watch to time oscillations was not a suitable method and was not awarded credit.

Candidates were then expected to explain how they would determine when the small mass left the plate. Vague methods using cameras and videos were not credited.

The majority of candidates understood which graph to plot, although a significant number of candidates incorrectly suggested plotting a graph of f against V. A small number of candidates received credit for relating the value for k to the gradient. For the mark to be awarded, k was expected to be subject of the formula. There was an additional detail mark available for stating the condition that the graph would be a straight line passing through the origin if the relationship was valid. These marks could be scored by plotting a log–log graph. In this case the analysis becomes more complicated and for the additional detail mark candidates would need to state the gradient of the straight line if the relationship was to be valid.

The mark for safety considerations required naming a safety device and the reason why it is used in the experiment. The safety precaution for this experiment was avoidance of being hit by the falling mass. Many candidates gave a standard list of safety items which were irrelevant. Candidates should be encouraged to think carefully about the specific experiment when deciding on the relevant safety considerations.

Candidates should be encouraged to write their plans including appropriate detail; often candidates' answers suggested that they did not have sufficient practical experience. Vague responses were not credited. Those candidates who have followed a 'hands on' practical course are generally much better placed to gain credit for additional detail. It is essential that candidates' 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 performance P of a motor vehicle is affected by the speed v of the vehicle.

(a) This question was generally answered well.

(b) A few candidates lost credit for rounding errors. Many candidates did not realise that for logarithmic quantities the number of significant figures corresponds to the number of decimal places in the logarithmic quantity. 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. Thus when P has a value given to three significant figures, lg P should be given to three (or four) decimal places. Determining the absolute uncertainty of lg P proved difficult for some candidates.

(c) (i) Plotting was well done, with only a very small number of candidates making unacceptably large plot markings. Error bars were generally correct.

(ii) There were fewer instances of thick lines, shaded lines and faint lines in the drawing of the graph. The worst acceptable line was not drawn accurately by a number of candidates.

(iii) This part was answered well. Most candidates clearly demonstrated the points they had used to determine the gradient. A few candidates did not use a sufficiently large triangle for their read-offs. The method of obtaining the uncertainty in the gradient was generally clearly set out. There were a few candidates who did not label the lines.

(iv) Most candidates used the equation $y = mx + c$ correctly to find the y-intercept by substituting the calculated gradient value and co-ordinates read from the drawn straight line. Some candidates did not realise that there was a false origin. To determine the uncertainty in the y-intercept, candidates had to determine the worst acceptable y-intercept by using the gradient from the worst acceptable line and a point on the worst acceptable line. Ratio methods cannot be used to find the uncertainty in the y-intercept. In calculating the uncertainty in the intercept, some candidates did not use the gradient or co-ordinates on the worst acceptable line.

(d) (i) Most candidates were awarded credit for the value of k. Some candidates were not awarded credit for m because the value was out of range, or did not have a minus sign, or the value was given with too many significant figures.

(ii) Many candidates did not realise that the percentage uncertainty in k is not equal to the percentage uncertainty of the y-intercept. Stronger candidates clearly showed working to indicate a worst value of k and then demonstrated how they determined the percentage uncertainty. Candidates who did not show working, or whose working was impossible to understand, could not be awarded credit.

PHYSICS

Paper 9702/52
Planning, Analysis and Evaluation

Key Messages

- In **Question 1**, candidates' responses should include detailed explanations of experimental procedures.
- 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 was an unfamiliar laboratory experiment. Candidates were required to plan an experiment to investigate how the intensity of the reflection of sound from a wall varies with the thickness of foam attached to the wall. Many candidates describing the method should have included more detail. Diagrams can be improved, particularly in the drawing of workable electrical circuits and using appropriate apparatus. The graphical analysis was generally understood and done well.

In **Question 2**, some candidates made rounding errors in the table of results. The plotting of points and error bars and the drawing of straight lines were generally done well. The reading of co-ordinates for the calculation of the gradient and calculation of the intercept was also generally good. Some errors were made in the analysis part at the end of the question. Many candidates did not show clear working.

It is clear that the stronger candidates 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 practical support booklets which are available from the Teacher Support Site.

Comments on Specific Questions

Question 1

Candidates were required to plan an experiment to investigate how the intensity of the reflection of sound from a wall varies with the thickness of foam attached to the wall. Candidates also needed to explain how to obtain an expression for the constant α – this should be explained using graphical analysis.

Most candidates correctly identified the independent and dependent variables.

Further credit is then available for controlling variables: candidates should indicate how a fair test could be carried out by keeping appropriate variables constant. Candidates should explicitly identify the variables that need to be kept constant; "controlled" is not an acceptable alternative to the word "constant". Examiners were expecting a reference to be made to keeping the distance from the wall/foam to the speaker/microphone constant and keeping the incident amplitude or incident intensity I_0 of the sound before reflection constant.

Five marks are available for methods of data collection. Candidates were expected to draw a labelled diagram of the apparatus. Labelled diagrams should be realistic in showing the laboratory setup. Stronger candidates drew a diagram that showed a method for producing sound (signal generator connected to a loudspeaker) and a method for detecting the reflected sound (microphone connected to a cathode ray oscilloscope).

There was a mark available for measuring the thickness of the foam with an appropriate instrument. Candidates also needed to specify how the density of foam would be determined. Stronger candidates stated the equation for density and then explained how to measure the mass (electronic balance/scales) and volume (length and width measured using a ruler).

The majority of candidates understood which graph to plot, although a number of candidates incorrectly suggested plotting a graph of I against t. For the second mark to be awarded, α was expected to be the subject of the formula. Some candidates clearly explained how α could be determined. Candidates who just stated "log" needed to include more detail.

The mark for safety considerations required naming a safety device and the reason why it is used in the experiment. The safety precaution for this experiment needed to be linked to loud sounds causing potential damage to ears, e.g. use ear plugs/muffs/defenders. Many candidates gave a standard list of safety items which were irrelevant. Candidates should be encouraged to think carefully about the specific experiment when deciding on the relevant safety considerations.

Candidates should be encouraged to write their plans including appropriate detail; often candidates' answers suggested that they did not have sufficient practical experience. Vague responses were not credited. Those candidates who have followed a 'hands on' practical course are generally much better placed to gain credit for additional detail. It is essential that candidates' 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 an experiment involving a circuit containing parallel plates separated by an insulator.

(a) This question was generally answered well.

(b) Some candidates lost credit for rounding errors. The determination of the uncertainties was generally well attempted.

(c) (i) Plotting was well done, with only a very small number of candidates making unacceptably large plot markings. Error bars were generally correct. Some candidates incorrectly plotted vertical error bars.

(ii) There were fewer instances of thick lines, shaded lines and faint lines in the drawing of the graph. The worst acceptable line was not drawn accurately by a number of candidates.

(iii) This part was answered well. Most candidates clearly demonstrated the points they had used to determine the gradient. A few candidates did not use a sufficiently large triangle for their read-offs. The method of obtaining the uncertainty in the gradient was generally clearly set out. There were a few candidates who did not label the lines. A number of candidates did not determine the gradient to the correct power of ten.

(d) (i) Most candidates obtained credit for the value of ε. For full credit, candidates needed to obtain an answer to the correct power of ten with an appropriate unit. A few candidates correctly gave $\mathrm{F\,m^{-1}}$. The common correct answers were $\mathrm{A\,m^{-1}\,V^{-1}\,Hz^{-1}}$ or $\mathrm{A\,s\,m^{-1}\,V^{-1}}$. Other correct units were credited. A number of candidates did not write a unit.

(ii) This was generally answered well; most candidates used a fractional method. Where errors occurred, candidates sometimes omitted quantities or subtracted the errors where quantities were divided. Candidates who used a maximum/minimum value method often made mistakes. Clear working needed to be shown for credit to be awarded.

(e) Many candidates did not determine the area of the square plates correctly and thus the answer for *f* was out of range. Some candidates gave an answer with too many significant figures. Stronger candidates clearly indicated appropriate substitutions and intermediate steps in their calculations.

To determine the absolute uncertainty if *f*, candidates had to show their working. Candidates who did not show working, or whose working was impossible to understand, could not be awarded credit.

PHYSICS

Paper 9702/53
Planning, Analysis and Evaluation

Key Messages

- In **Question 1**, candidates' responses should include detailed explanations of experimental procedures.
- 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 was an unfamiliar laboratory experiment. Candidates were required to plan an experiment using a vibrator at a given potential difference to determine the maximum frequency of an oscillating metal plate at which a small mass remains in contact with the plate. Many candidates describing the method should have included more detail. Diagrams can be improved, particularly in the drawing of workable electrical circuits. The graphical analysis was generally understood and done well. Many candidates did not provide enough additional detail to receive credit; for example, many candidates could not describe the use of an oscilloscope to measure frequency.

Question 2 required the candidates to plot a log–log graph. Many candidates made rounding errors in the table of results and/or quoted values of log *P* to too few decimal places. The plotting of points and error bars and the drawing of straight lines were generally done well. The reading of co-ordinates for the calculation of the gradient and calculation of the intercept was also generally good. Some errors were made in the analysis part at the end of the question.

It is clear that the stronger candidates 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 practical support booklets which are available from the Teacher Support Site.

Comments on Specific Questions

Question 1

Candidates were required to plan an experiment using a vibrator at a given potential difference to determine the maximum frequency of an oscillating metal plate at which a small mass remains in contact with the plate. Candidates also needed to explain how to obtain an expression for the constant *k* – this should be explained using graphical analysis.

Most candidates correctly identified the independent and dependent variables. Many candidates did not receive further credit for defining the experiment. Candidates needed to explain that they would adjust the frequency until the small mass just left the plate for a given alternating potential difference or, alternatively, candidates needed to explain that they would adjust the alternating potential difference until the small mass just left the plate for a given frequency.

Further credit is then available for controlling variables: candidates should indicate how a fair test could be carried out by keeping appropriate variables constant. Candidates should explicitly identify the variables that need to be kept constant; "controlled" is not an acceptable alternative to the word "constant". Examiners were expecting a reference to be made to keeping the position of the mass 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 vibrator connected with two leads to a signal generator. Labelled diagrams should be realistic in showing the laboratory setup. It was also expected that there would be a voltmeter or cathode-ray oscilloscope correctly positioned to determine the alternating potential difference. The circuit must be workable. In any electric circuit, voltmeters and cathode-ray oscilloscopes must be connected in parallel with the component across which the potential difference is to be measured.

A mark was available for measuring the frequency from the cathode-ray oscilloscope or signal generator. There were two additional detail marks available for explaining how to determine the period from a cathode-ray oscilloscope and hence the frequency. Using a stop watch to time oscillations was not a suitable method and was not awarded credit.

Candidates were then expected to explain how they would determine when the small mass left the plate. Vague methods using cameras and videos were not credited.

The majority of candidates understood which graph to plot, although a significant number of candidates incorrectly suggested plotting a graph of f against V. A small number of candidates received credit for relating the value for k to the gradient. For the mark to be awarded, k was expected to be subject of the formula. There was an additional detail mark available for stating the condition that the graph would be a straight line passing through the origin if the relationship was valid. These marks could be scored by plotting a log–log graph. In this case the analysis becomes more complicated and for the additional detail mark candidates would need to state the gradient of the straight line if the relationship was to be valid.

The mark for safety considerations required naming a safety device and the reason why it is used in the experiment. The safety precaution for this experiment was avoidance of being hit by the falling mass. Many candidates gave a standard list of safety items which were irrelevant. Candidates should be encouraged to think carefully about the specific experiment when deciding on the relevant safety considerations.

Candidates should be encouraged to write their plans including appropriate detail; often candidates' answers suggested that they did not have sufficient practical experience. Vague responses were not credited. Those candidates who have followed a 'hands on' practical course are generally much better placed to gain credit for additional detail. It is essential that candidates' 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 performance P of a motor vehicle is affected by the speed v of the vehicle.

(a) This question was generally answered well.

(b) A few candidates lost credit for rounding errors. Many candidates did not realise that for logarithmic quantities the number of significant figures corresponds to the number of decimal places in the logarithmic quantity. 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. Thus when P has a value given to three significant figures, lg P should be given to three (or four) decimal places. Determining the absolute uncertainty of lg P proved difficult for some candidates.

(c) (i) Plotting was well done, with only a very small number of candidates making unacceptably large plot markings. Error bars were generally correct.

(ii) There were fewer instances of thick lines, shaded lines and faint lines in the drawing of the graph. The worst acceptable line was not drawn accurately by a number of candidates.

(iii) This part was answered well. Most candidates clearly demonstrated the points they had used to determine the gradient. A few candidates did not use a sufficiently large triangle for their read-offs. The method of obtaining the uncertainty in the gradient was generally clearly set out. There were a few candidates who did not label the lines.

(iv) Most candidates used the equation $y = mx + c$ correctly to find the y-intercept by substituting the calculated gradient value and co-ordinates read from the drawn straight line. Some candidates did not realise that there was a false origin. To determine the uncertainty in the y-intercept, candidates had to determine the worst acceptable y-intercept by using the gradient from the worst acceptable line and a point on the worst acceptable line. Ratio methods cannot be used to find the uncertainty in the y-intercept. In calculating the uncertainty in the intercept, some candidates did not use the gradient or co-ordinates on the worst acceptable line.

(d) (i) Most candidates were awarded credit for the value of k. Some candidates were not awarded credit for m because the value was out of range, or did not have a minus sign, or the value was given with too many significant figures.

(ii) Many candidates did not realise that the percentage uncertainty in k is not equal to the percentage uncertainty of the y-intercept. Stronger candidates clearly showed working to indicate a worst value of k and then demonstrated how they determined the percentage uncertainty. Candidates who did not show working, or whose working was impossible to understand, could not be awarded credit.