PHYSICS

Paper 9702/11
Multiple Choice

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

General comments

This multiple choice paper is set on just the AS part of the syllabus. Since the paper has 40 questions there must of necessity be many questions on Newtonian mechanics, matter, waves and current electricity. Candidates should be made thoroughly aware of this so that these basic topics are thoroughly understood and with plenty of practice being done in advance of sitting the paper. Instant recall of basic mechanical and electrical formulae is essential if 40 questions are to be answered within the time limit of an hour. Untidy working with lots of numbers can lead to many mistakes. A quick and fool-proof system is to incorporate units when working numerical problems as it will immediately indicate a mistake if the units of the answer are incorrect. Generally candidates do not have sufficient time to check through the paper at the end of the examination, so answers have to be correct within a minute and a half. Candidates must know that they should not spend too long on any one question. They must manage their time to ensure that they do not find they have 15 questions still to answer with only 2 minutes left of the allowed one hour.

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Comments on specific questions

Only **Questions 1, 3** and **8** had facility over 80%.

Question 9

70% of candidates incorrectly thought that the final momentum was $2mv$.

Question 10

39% of candidates incorrectly thought that zero was the change in the momentum.

Question 13

All four options were more or less equally chosen, suggesting that many candidates guessed rather than using up time doing a proper analysis. 33% did get the correct answer, however.

Question 14

B was chosen more frequently than the correct answer **C**.

Question 18

B and **C** were equally chosen, no doubt assuming that, because evaporation takes place without (for example) an electrical supply, it does not require energy. Evaporation does require energy.

Question 25

The most difficult question on the whole paper with only 16% of candidates choosing the correct answer. Candidates needed to realise that the length of the horn is $\lambda/4$ for the 75 Hz note and that the next overtone will be for 3/4 of the new wavelength, giving a frequency of 225 Hz.

Question 27

Many candidates just looked at the arrows here and thought the answer was 3.

Question 32

Only 29% were correct here. All the answers were chosen roughly equally, indicating that candidates would benefit from further study of e.m.f. and potential difference.

Question 35

Many candidates used pseudo-proportion here and found 2/8 of 5 A as their answer. It is tempting to do this but the method is seriously flawed.

Question 36

This is another tricky problem that only the more able candidates could answer. 50% of candidates incorrectly thought that **D** was the correct answer.

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PHYSICS

Paper 9702/12
Multiple Choice

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

General comments

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Comments on specific questions

It transpired that there were 8 questions that had facility over 80 %. These were **Questions 1, 5, 11, 27, 36, 38, 39** and **40**.

Question 7

32% of candidates could work with the artificial zero of displacement at $t = 0$. Of the remaining candidates 44% gave the incorrect answer **C**.

Question 8

Only 36% of candidates answered this correctly. Both **B** and **D** were popular incorrect answers. This graph starts as a parabola since it is initially a graph of $s = ½gt^2$ until air resistance reduces the acceleration to 0.

Question 16

28% of candidates thought that **B** was correct and 39% chose **D**. The correct answer was given by only 25%. Taking moments about X gives $10 \times ½l = F \cos 60° \times l$.

Question 31

D was chosen more frequently than the correct answer **B**. Many candidates did not see the significance of the word 'increasing'. The force will not increase in a uniform field.

Question 34

A significant number of candidates would benefit from further study of learning objective 19(o) in the syllabus, as only 41% of candidates gave the correct answer, **D**.

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PHYSICS

Paper 9702/13
Multiple Choice

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

General comments

This multiple choice paper is set on just the AS part of the syllabus. Since the paper has 40 questions there must of necessity be many questions on Newtonian mechanics, matter, waves and current electricity. Candidates should be made thoroughly aware of this so that these basic topics are thoroughly understood and with plenty of practice being done in advance of sitting the paper. Instant recall of basic mechanical and electrical formulae is essential if 40 questions are to be answered within the time limit of an hour. Untidy working with lots of numbers can lead to many mistakes. A quick and fool-proof system is to incorporate units when working numerical problems as it will immediately indicate a mistake if the units of the answer are incorrect. Generally candidates do not have sufficient time to check through the paper at the end of the examination, so answers have to be correct within a minute and a half. Candidates must know that they should not spend too long on any one question. They must manage their time to ensure that they do not find they have 15 questions still to answer with only 2 minutes left of the allowed one hour.

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Comments on specific questions

It transpired that there were 10 questions that had facility over 80 %. These were **Questions 1, 2, 5, 6, 13, 16, 19, 20, 30** and **40**.

Question 10

56% of candidates incorrectly thought that the final momentum was 2*mv*.

Question 12

All four options were more or less equally chosen, suggesting that many candidates guessed rather than using up time doing a proper analysis. 30% did get the correct answer, however.

Question 15

Only 29% of candidates were able to get the loss of potential energy as 58.8 J and the work done against friction as 35 J, leaving the kinetic energy at the bottom as 23.8 J, corresponding to a speed of 4.9 $m\,s^{-1}$. 36% thought that **B** was the correct answer.

Question 21

Most candidates, 71%, did not know that the elastic limit is normally just beyond the limit of proportionality.

Question 26

Many candidates just looked at the arrows here and gave the incorrect answer 3. Only 19% of candidates worked out the answer correctly; three on either side plus the straight through beam.

Question 27

Candidates needed to realise that the length of the horn is $\lambda/4$ for the 75 Hz note and that the next overtone will be for 3/4 of the new wavelength, giving a frequency of 225 Hz. Only 24% did this correctly.

Question 31

Only 38% were correct here. **B** was chosen as often as the correct answer **A**. Candidates would benefit from further study of e.m.f. and potential difference.

Question 33

This is another tricky problem that only the more able candidates could answer. 41% of candidates thought that **D** was the correct answer.

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PHYSICS

Paper 9702/21

AS Structured Questions

Key messages

- As always, candidates should be encouraged to read each question carefully before answering, paying particular attention to command words such as 'state' or 'explain' which each require different types of response.
- Many candidates would benefit from taking a moment to consider the numerical answers that they have obtained, especially as regards powers of ten. A quick check on whether an answer is 'reasonable' would allow candidates to detect errors in their working.
- Candidates should be encouraged not to 'round off' answers at intermediate stages of a calculation, as this can lead to inaccurate and inappropriate final answers.
- Candidates should be advised to use the data given on page 2 of the question paper. In particular, the use of the approximation $g = 10\,\mathrm{m\,s^{-2}}$ should be discouraged.

General comments

There were comparatively few candidates who maintained a constant good standard for their answers throughout the whole paper. It would appear that some areas of the syllabus required further attention during preparation for the examination, especially the topic of 'Waves'.

In comparison with recent papers, there was a welcome reduction in the number of candidates quoting answers to an unreasonable number of significant figures. However, this has led to an increase in the practice of 'rounding off' answers at intermediate stages of a calculation. This 'rounding off' should be discouraged since it leads to inaccurate and inappropriate final answers.

Comments on specific questions

Question 1

(a) Appropriate instruments included a metre rule for the length, a micrometer screw gauge for the diameter and an ammeter and voltmeter for the resistance. Many suggested vernier calipers for the diameter. It was surprising that a common answer for the resistance was 'a resistor', suggesting perhaps that candidates had misread the question.

(b)

(i) Most candidates quoted a correct expression for resistivity. The most common error was in the calculation of the cross-sectional area.

(ii) It was common to find that the calculated uncertainty was many times greater than the actual value for the resistivity. Candidates should be encouraged to explain their work and to write it down in a neat and logical manner. Credit can not be awarded if it is not possible to understand how answers have been derived.

There were comparatively few answers where the fractional uncertainty in the diameter was doubled in order to determine the fractional uncertainty in the area.

(c) When quoting final answers, candidates should give the uncertainty to one significant figure. The resistivity should then be given to the same number of decimal places as the quoted uncertainty.

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Question 2

(a) Most candidates attempted to define work done, rather than explain its meaning. This approach was acceptable. In many answers there was a reference to the product of force and distance without making it clear that the distance is that moved in the direction of the force.

(b) In most answers, it was realised that a trigonometrical function of the angle is involved but there was widespread confusion between the use of sin 7.5° and cos 7.5°.

(c)

(i) In most answers, the component of the weight was subtracted from the force resisting motion before determining the acceleration. This calculation involved arriving at a given answer. The method and the substitution were equally important. No benefit is gained from quoting the correct answer when the working is inappropriate.

(ii) This calculation was completed successfully by most candidates.

(iii) Apart from power-of-ten errors, these two calculations gave rise to very few problems.

(iv) Very few responses made any reference to the loss in gravitational potential energy. The usual answers were energy loss due to either 'friction' or 'heat'.

Question 3

(a) It was expected that candidates would realise that the centre of gravity is the point where the whole weight of the body *appears* to act. In a significant number of scripts, the weight was said to be concentrated at this point. A small number of candidates referred to mass, rather than weight.

(b) It was expected that candidates would refer to *perpendicular* distance, rather than merely distance.

(c)

(i) In most scripts, reference was made both to forces and to moments. The essential feature that it is the sum or the resultant that is zero was frequently omitted. Statements such as 'clockwise moment equals anticlockwise moment' were common.

(ii) There were many correct solutions that were given with adequate explanation. Common errors were to take moments about the pivot and then to either not include the moment due to the weight of the plank or to give the distance of the student from the pivot as 0.3 m.

(iii) It would appear that a significant number of candidates misread the question in that they suggested that the 70 N weight should be moved.

Question 4

(a) The majority of answers for both stress and strain were acceptable. Candidates should be aware of the fact that the definitions are given in terms of cross-sectional area and of original length.

(b)

(i) The majority of answers were correct. Where an incorrect answer was given, this was frequently associated with not giving the expression for the Young modulus in symbols. Candidates should be encouraged to consider the answers that they have obtained, especially as regards any power of ten. Answers of the order of 10^{21} m for the extension are, clearly, incorrect. Any candidate who has laboratory experience of this situation should realise that extensions of the order of mm are appropriate.

(ii) There were few correct answers. Most considered a change due to either the change in length of the wire or the change in cross-sectional area, but not both. Consequently, the usual answer was a doubling of the extension.

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Question 5

(a)

(i) With few exceptions, the correct answer was given. A significant number of candidates did assume that the total resistance of the circuit would be 12 Ω and thus gave the current as being 1.0 A.

(ii) There were few acceptable sketches. Many candidates did not have the line commencing at (0.0, 2.0) but instead, started at (6.0, 2.0). Others continued the line beyond R = 12 Ω. There were very few graphs where the line was drawn as an appropriate curve between the two end points.

(b) There were very few correct answers, with many giving an incorrect value of 3.0 A for the maximum current and then not giving an answer for the minimum. Candidates should be encouraged to study this application of the potential divider.

(c)

(i) It was expected that the sketching of this graph would present few problems. This was not the case, with only a minority scoring full credit. Where an acceptable line was drawn for low values of V, the curve frequently showed constant current at higher values of V.

(ii) Most answers were concerned with the maximum current that could be achieved rather than the fact that, with the potential divider, the full range of currents is possible.

Question 6

(a) Candidates should make reference to the atoms/molecules/particles of the gas. In many answers, it was the gas itself that was said to be in random motion. A common misconception was that the mass of the atoms is negligible.

(b) Very few candidates were able to progress beyond a statement that the gas atoms would collide with the walls of the containing vessel. It was expected that this statement would be followed by an argument based on the change in momentum of the atom being caused by a force exerted by the wall on the atom and that there would be an equal but opposite force exerted by the atom on the wall. Many such collisions per unit time would average out to give a steady force/pressure.

Question 7

(a) Explanations were, almost invariably, incomplete. It was realised that interference occurs when waves meet at a point. The result was usually expressed in very simple terms such as ‘the production of crests and troughs’. Candidates should provide a clear statement that the resultant displacement is given by the sum of the individual displacements.

(b)

(i) Most answers were limited to a description of some form of dipper or dippers, without there being any clear means by which coherent waves would be produced. Either the two dippers must be driven by the same source of vibrations or a single dipper should be placed behind a double slit.

(ii) A significant number of candidates did not attempt this part of the question and many others misread the question. Instead of describing how the waves would be observed, they attempted to describe what would be seen. Of those who did describe the use of an appropriately placed light source and screen, very few included some form of strobe.

(c) There were many scripts where this part of the question was not attempted. Where lines were drawn, many showed the line for minima as being in the position of the zero order maximum.

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PHYSICS

Paper 9702/22
AS Structured Questions

Key messages

- As always, candidates should be encouraged to read each question carefully before answering, paying particular attention to command words such as 'state' or 'explain' which each require different types of response.
- Many candidates would benefit from taking a moment to consider the numerical answers that they have obtained, especially as regards powers of ten. A quick check on whether an answer is 'reasonable' would allow candidates to detect errors in their working.
- Candidates should be encouraged not to 'round off' answers at intermediate stages of a calculation, as this can lead to inaccurate and inappropriate final answers.
- Candidates should be advised to use the data given on page 2 of the question paper. In particular, the use of the approximation $g = 10\,\text{m}\,\text{s}^{-2}$ should be discouraged.

General comments

There were comparatively few candidates who maintained a constant good standard for their answers throughout the whole paper. It would appear that some areas of the syllabus required further attention during preparation for the examination. The main topics where this was particularly apparent were 'Deformation of Solids', 'Electricity' and 'Waves'.

Questions 1, **2** and **3** were accessible to the majority of candidates. **Questions 4** and **5** seemed to cause the most difficulty to all candidates. There did not appear to be any problem in candidates completing the paper in the time available.

There appeared to be a welcome reduction in the number of candidates quoting an inappropriate number of significant figures. There seemed to be an increase in the practice of 'rounding off' answers at intermediate stages of a calculation. This 'rounding off' should be discouraged since it leads to inaccurate and inappropriate final answers.

Many candidates did not seem to read **Questions 1(b)**, **2(b)** and **4** sufficiently carefully.

Comments on specific questions

Question 1

There were parts of this question that were accessible to all candidates. There were many candidates who were able to give well-presented correct answers to almost all parts of the question.

(a) The majority of candidates gave a clear explanation of the difference between scalars and vectors. A few candidates referred to vector quantities requiring a direction and scalar quantities not, with no reference to magnitude.

(b) Almost all candidates could quote the difference between scalars and vectors in **(a)**. However, there were many candidates who were unable to apply this knowledge in **(b)**. The majority of candidates knew that mass was a scalar quantity but a significant number did not include power or kinetic energy. Weight was also included by some candidates as a scalar. There was a significant

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minority of candidates who only underlined one quantity (usually mass) or who appeared to miss out this part.

(c)

(i) There were many well-presented correct answers. Candidates need to be advised to treat the horizontal and vertical directions independently. The horizontal velocity was sometimes used by candidates to calculate the time of fall assuming constant velocity. The equations used by some candidates either assumed no acceleration for the fall vertically or used the initial horizontal velocity as the initial vertical velocity. There were only a few candidates who incorrectly rounded their answer to 1.8 s.

(ii) There were many well-presented correct answers. Candidates need to be advised to treat the horizontal and vertical directions independently in such questions. The initial horizontal velocity was used by some candidates as the initial vertical velocity. The final vertical velocity was also given as the resultant velocity. There were many candidates who were not aware that the resultant velocity is found by the vector addition of the horizontal and vertical velocities.

(iii) There were very few descriptions that clearly showed the distinction between the displacement and the distance travelled by the stone. A significant number of candidates gave an acceptable description of displacement. This answer was spoilt by some candidates who then quoted the vertical height of 15 m as the displacement of the stone. Candidates had more difficulty describing the distance and few referred to the path of the stone. Those candidates who drew a diagram often gave excellent answers.

Question 2

There were parts of this question that were accessible to all candidates. There were many candidates who found **(a)(ii) part 2** and **(b)(ii)** difficult.

(a)

(i) There were many well-presented correct answers. In 'show that' questions, candidates should be advised to show all their working. In this question credit was awarded where candidates clearly gave the SI base units for each of the quantities in the given equation.

(ii) **1**. The majority of answers were correct. The majority of candidates correctly converted the radius given in millimetres to metres.

2. The correct mass of the raindrop was calculated by many of the candidates. The formula for the volume of a sphere was not known by a significant number of candidates. Very few candidates determined the acceleration by calculating the resultant force acting on the raindrop. The majority assumed that the frictional force was the resultant force and ignored the weight of the drop. Candidates should consider the force F in the equation $F = ma$ as the resultant force.

(b)

(i) The majority of candidates described the variation in acceleration correctly for the mid and last sections of the graph. Very few described the acceleration at the start being that of free fall but most gave the acceleration at the end as zero. There were many misconceptions given by a significant number of candidates. The acceleration was stated as zero at the start and then increasing before decreasing to a constant value. Other statements suggested a deceleration and the velocity decreasing as the acceleration decreased. Candidates should be advised that the command word 'state' in a question does not require explanations. Many of the answers given included explanations of why the acceleration was changing. These answers were not required. A significant minority of candidates did not read the question carefully and gave descriptions of the changes in the velocity.

(ii) A minority of candidates gave the correct sketch. A smaller terminal velocity at an earlier time for the raindrop with a smaller radius was not given by the majority of candidates. A significant number of candidates gave an initial curve below the existing curve but then went on to suggest the same terminal velocity for both raindrops. Most candidates drew lines above the existing line. Candidates should be advised to draw sketches on the Figure given in the question where they are instructed so to do. There were a significant number of

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candidates that drew a separate graph. The curve on this graph could not be compared to the curve in Fig. 2.1 and hence no credit could be given.

Question 3

This question was found to be accessible to the majority of candidates.

(a)

(i) The majority of candidates gave an acceptable explanation of work done. Candidates should be advised that, at this level, work done being the product of force and distance is not acceptable. Candidates need to refer to the distance as the distance moved in the direction of the force.

(ii) The definition of power was given correctly by the majority of candidates.

(b)

(i) The correct answer was calculated by the majority of candidates. A few candidates did not square the velocity in their calculation or convert from joules to kilojoules.

(ii) Candidates generally gave all the necessary working in this part to show the given value of the gain in potential energy. Candidates needed to ensure that all the analysis was given including the conversion of their answer in joules to kilojoules. A significant number did not do this and could not be awarded full credit.

(iii) The majority of candidates calculated the difference in the kinetic and potential energies and related this to the work done against the resistive force. A significant number of candidates were not able to do this. Some added the two energies together and others tried to calculate work done using a component of the weight along the slope.

(iv) A significant number of candidates who were able to complete **(b)(iii)** made errors in this part. The distance along the slope was miscalculated or the conversion from kilojoules to joules was neglected. In many answers where it was realised that a trigonometrical function of the angle was involved in determining the distance up the slope, there was widespread confusion between the use of sin 30°, cos 30° and tan 30°.

Candidates should be made aware that calculations in such questions will not always involve all the kinetic energy being converted into potential energy or vice versa.

Question 4

This question proved to be difficult for the majority of candidates. There were many candidates who did not read the question carefully and follow the instructions given for each part. A significant number of candidates did not seem to realise that specific responses were required in each part of the question. There were a significant number of candidates who did not appear to be aware of this particular experiment. There were a number of candidates that gave no response for this question.

(a) The majority of diagrams that were drawn were very vague consisting of a wire and a load supported by a stand and clamp or no labelled support at all. Labelling was generally poor. Some candidates merely drew individual pieces of apparatus that were not assembled. Candidates should be advised that there is no credit for such a response. Those candidates that used Searle's apparatus often confused a vernier scale with vernier calipers. Scales near the wire and reference marks on the wire were seldom shown or described by candidates. Poor answers involving springs were seen from a large number of candidates.

(b) The descriptions of the method of obtaining the measurements were often far too vague. The actual length of wire being measured to a reference mark on the wire and the instrument used was seldom described. A micrometer was often stated as being used to measure the cross-sectional area or the radius instead of the diameter. Candidates mentioned determining the extension but the method of measuring the initial and final readings and with what instrument was seldom described. Very few made a reference to recording the mass/weight used to produce the extension. A minority referred to taking a series of readings with a range of weights.

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(c) There were only a small minority of candidates that described how the collected raw data should be used. Some candidates were awarded credit for a definition of stress and strain and relating these quantities to the Young modulus. A very small minority considered plotting a graph. Very few candidates appreciated that an explanation was needed of how the readings described in **(b)** are processed in order to obtain a value for the Young modulus.

Question 5

The majority of candidates did not give good responses for this question.

(a)

(i) The explanation given by the majority of candidates was insufficient to gain any credit. Very few referred to chemical energy being converted to electrical energy when charge moved through the cell.

(ii) The majority of answers were a statement that internal resistance is the resistance inside the cell. This received no credit.

(b)

(i) A minority of candidates were able to apply Kirchhoff's law to the circuit and obtain a correct value for the current in the circuit. The majority made errors that included adding the e.m.f.s of the two cells and not adding the potential difference across all the resistances in the circuit correctly. Candidates should be encouraged to practice applying Kirchhoff's laws to such circuits.

(ii) More candidates were able to gain credit for the calculation of the power transformed with error carried forward from **(i)** as they used the appropriate equation $P = EI$. There were a significant number of candidates who used an invalid expression for the power. The most common invalid equation was V^2 / R with the e.m.f. of the battery used for V and the internal resistance used for R.

(iii) Candidates who obtained credit for **(i)** and **(ii)** generally calculated the energy lost per second and the resistances correctly. Many candidates used an inappropriate equation or made errors with the resistances included in the calculation.

(c) This part was only accessible to those candidates who had answers in **(b)** that they could use to support their suggestion. The correct answer was given by a significant number of candidates who had the necessary evidence.

Question 6

(a)

(i) A majority of candidates realised the need for coherent sources for this experiment. A significant minority suggested that two sources would not give the same wavelength or frequency.

(ii) The phase difference was not given correctly by the majority of candidates. Incorrect values were often given or values were given for the path difference in terms of wavelength. Many candidates did not gain credit as they gave answers without units.

(iii) **1**. The principle of superposition was given correctly by a significant number of candidates. However, answers were spoilt by the omission of key words. The waves need to 'overlap' and the resultant 'displacement' is required rather than the resultant amplitude. Stating that the waves need to superpose merely repeats the question and does not help in the explanation of superposition.

2. The explanation in terms of the principle of superposition of the dark fringe at P was only given by a minority of candidates. The answers were generally too vague with many stating that there was destructive interference with no reference to the relevant principle.

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(b) The correct equation was generally known and given with acceptable symbols. The fringe width was often not substituted into the equation correctly as a factor of two was omitted. A number of candidates were unable to convert the answer calculated in metres into nanometres. The use of non-conventional symbols with the subsequent wrong substitution of values meant that some candidates did not score the credit available for the correct equation.

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PHYSICS

Paper 9702/23

AS Structured Questions

Key messages

- As always, candidates should be encouraged to read each question carefully before answering, paying particular attention to command words such as 'state' or 'explain' which each require different types of response.

- Many candidates would benefit from taking a moment to consider the numerical answers that they have obtained, especially as regards powers of ten. A quick check on whether an answer is 'reasonable' would allow candidates to detect errors in their working.

- Candidates should be encouraged not to 'round off' answers at intermediate stages of a calculation, as this can lead to inaccurate and inappropriate final answers.

- Candidates should be advised to use the data given on page 2 of the question paper. In particular, the use of the approximation $g = 10\,\mathrm{m\,s^{-2}}$ should be discouraged.

General comments

There were comparatively few candidates who had prepared well across all the learning objectives. These candidates were able to produce good answers to all the questions on the paper. There were many candidates where some areas of the syllabus required further attention during preparation for the examination. The topics where this was most apparent were 'Electricity' and 'Waves'.

There seemed to be an apparent increase in the practice of 'rounding off' answers at intermediate stages of a calculation. This 'rounding off' should be discouraged since it can lead to inaccurate and inappropriate final answers.

Comments on specific questions

Question 1

The majority of candidates made a good start to the paper showing a good understanding of experimental errors. A significant minority showed a lack of preparedness in this part of the syllabus.

(a) The majority of candidates obtained full credit. There were a significant number who confused systematic and random errors. The use of a linear scale also suggested to some candidates that there would be a reduction in the systematic error.

(b)

(i) **1**. This part reinforced the candidates' understanding of systematic errors and there were many good responses.

2. This part reinforced the candidates' understanding of random errors and there were many good responses.

(ii) **1**. There were a significant number of candidates who clearly understood the difference between accuracy and precision. They were also able to describe the changes that would be observed in results if the readings were more accurate. Many candidates were unable to state the changes to the results and hence the changes to Fig. 1.1 if the readings were more accurate.

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2. The answers given by a significant number of candidates described a modification to the experimental technique or the choice of measuring instrument. They did not answer the question and describe the changes that would occur to Fig. 1.1. The changes to the readings when the results are more precise were known by only a small number of candidates.

Question 2

There were many good responses to this question.

(a) Candidates were generally able to give at least one of the conditions required for equilibrium. Credit was not obtained by candidates who did not refer to the resultant force being zero or to the sum of the clockwise moments being equal to the sum of the anticlockwise moments.

(b) The vector triangle was drawn with the correct orientation and labels by the majority of candidates. Credit was not obtained by candidates with triangles that were not labelled with the forces and/or the angles. A small minority gave the forces in the wrong direction.

(c)

(i) The vector triangle was used correctly by the majority of candidates.

(ii) A significant number of candidates made an error with the trigonometrical function chosen to relate the forces represented by the sides of the triangle and hence obtained an incorrect answer for *R*.

(d) Candidates who quoted the equation from their working in **(c)(i)** to calculate the tension produced good explanations. In general the answers given needed a greater amount of detail to gain full credit.

Question 3

(a) The majority of candidates were able to correctly calculate the weight from the given mass.

(b)

(i) The majority of candidates proposed that the tension produced the acceleration. A minority of candidates considered the resultant force to be the tension minus the weight.

(ii) The majority of candidates gave the correct answer. A significant number of candidates did not associate a zero resultant force with the constant velocity.

(c) The majority of candidates again ignored the effect of the weight on the resultant force.

(d)

(i) **1**. A small minority of candidates used the value given for the acceleration to calculate the time taken to reach constant velocity.

2. A small minority of candidates were able to calculate the time taken to decelerate.

Candidates should be encouraged to use the equations of uniform acceleration when the term 'uniform' is stated in the question.

(ii) The candidates with correct answers for **(d)(i)** generally drew accurate graphs. There were some candidates who made errors when reading the time scale. The values given on the time axis and the time given for the journey at constant velocity should have given candidates a guide to the expected graph.

Question 4

(a) A significant number of candidates were unable to state Hooke's law correctly. Candidates should be advised that a relationship involving symbols is not given any credit unless the symbols are defined.

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(b)

(i) There were a significant number of candidates who obtained an appropriate value for the spring constant. There are two main methods that could improve the answers obtained by candidates. The compression on the graph was given in millimetres. Candidates should be advised to convert to metres in the calculation for the spring constant. The coordinates used from the graph need to be read accurately. Candidates should select points from the line that are easy to read from the axes.

(ii) The value given for the work done enabled a significant number of candidates to show the correct working. There were a significant number of candidates who clearly changed the presentation of their working to fit the required answer. In general the method for obtaining the work done compressing a spring was not known by many of the candidates.

(c)

(i) The majority of candidates knew the expression for the kinetic energy and correctly calculated the speed of the ball. Very few candidates did not convert the mass from grams into kilograms.

(ii) The more able candidates correctly determined the compression needed to give the increased speed. The majority of candidates were not able to relate the increased speed with the correct increase in kinetic energy and hence work done on the spring.

(iii) The ratio was correctly calculated by the candidates with high ability. There were a significant number of well-presented answers from these candidates.

Question 5

This question was poorly answered by the majority of candidates.

(a)

(i) The characteristic for a filament lamp was generally poorly drawn. The lines were seldom drawn with enough care to produce a smooth curve that did not become horizontal.

(ii) The majority of answers did not refer to the co-ordinates of a point on the characteristic. The two most common explanations that did not gain credit were to give the equation that defines resistance without further comment or a description to determine the resistance from the inverse of the gradient of the line.

(b)

(i) There were some good answers where candidates realised that the potential difference across the lamps in the two circuits was different. The effect of a higher potential difference producing a higher temperature and hence a higher resistance for the lamp was seldom explained by candidates. A large proportion of candidates did not read the question carefully. The answers given by these candidates were related to the total resistance for resistors connected in parallel compared with the resistors connected in series.

(ii) The resistance of a lamp under the conditions stated was calculated correctly by a large proportion of the candidates. More able candidates went on to calculate the total resistance for the lamps connected in parallel. A significant number of candidates calculated the total resistance for the lamps connected in series or did not calculate a total resistance. The connection between the rating given for the lamp and the circuit that provided the lamp with 12 V was not made by these candidates.

Question 6

A large majority of candidates produced good answers to **(a)** and **(b)** but then did not answer **(c)** to the same standard.

(a)

(i) This was generally well answered. Only a small minority misread the scale on the graph. The vast majority understood the term ‘amplitude’.

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(ii) The term 'phase difference' was not known or understood by the majority of candidates. There were many incorrect answers that referred to wavelength. Credit was not given when the unit was omitted.

(iii) The vast majority of candidates obtained the correct answer. There were a few candidates who seemed to be unaware of the need to convert the wavelength determined from the graph in centimetres into metres when the speed of the wave is required in m s^{-1}.

(b) There were many good sketches drawn of the new position of the wave. A few candidates were unable to relate the distance moved by wave in the given time to the wavelength of the wave. Candidates also need to read the question carefully as some missed the reference to the frequency and were unable to complete **(a)(iii)**, and some drew a new wave with a frequency four times the one given in the question.

(c)

(i) The term 'phase difference' was not known or understood by the majority of candidates.

(ii) The terms 'antinode' and 'node' needed to be described with reference to amplitude. Candidates seldom gave this explanation.

(iii) The answers given by candidates suggested a general confusion between antinodes and nodes.

(iv) There were very few correct sketches drawn of the new position of the wave. The majority of candidates drew a travelling wave rather than a stationary wave. Candidates need to know the variations in the positions of a stationary wave as it vibrates.

Question 7

(a) The majority of candidates gave the correct variation in spacing between molecules in solids, liquids and gases. Only a few candidates went on to answer the question fully and relate the spacing to the densities of solids, liquids and gases. There were very few comparisons made between the densities that were related to the spacing of the molecules.

(b) The majority of candidates gave the correct expression for density in terms of mass and volume. A significant number went on to correctly calculate the density of the hydrogen nucleus. Candidates need to know the volume of a sphere to enable such calculations.

(c) A significant number of candidates were able to describe the reason for the large difference in density between the hydrogen gas and hydrogen nucleus. Candidates need to know that a large proportion of the volume of an atom and a gas is composed of free space.

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PHYSICS

Paper 9702/31

Advanced Practical Skills 1

Key messages

- The skills tested in **Question 1** are listed in detail in Syllabus section 5.2. Candidates need experience of using the relevant measuring equipment, and must be able to present results and calculations clearly to score high marks.

- Candidates should aim to make graphical work user friendly and choose appropriate scales to make finding points and interpreting gradient read-offs easy. Candidates should be encouraged not to make the plots occupy the whole grid by using awkward scales. As long as the plots occupy half of the grid, it is possible for sensible scales to be used at all times.

- **Question 2** tests some of the same skills but it also requires discussion about the design of the experiment. Marks are available for explaining why some measurements have large uncertainties and for suggesting how these could be improved by using different measuring equipment or by changed procedures. There are not often many 'standard' answers – careful consideration of the individual experiment is needed.

General comments

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

The great majority of Centres had no difficulties in providing the equipment required for use by candidates. Any deviation between the requested equipment and that provided to candidates should be written down in the Supervisor's Report as well as notifying Cambridge so that the Examiners can take this into consideration during the marking period. Any help given to a candidate should be noted on the Supervisor's Report. Supervisors are reminded that under **no circumstances** should help be given with the recording of results, graphical work or analysis.

Candidates did not seem to be short of time and both questions were attempted. Candidates were reasonably confident in the generation and handling of data. They can improve by giving more thought to the critical evaluation of experiments. There are a number of Centres where the candidates can improve their performance considerably by including all raw values of their data expressed to a degree of precision consistent with the instrument being used and ensuring final answers have an appropriate unit.

There were no common misinterpretations of the rubric.

Comments on specific questions

Question 1

In this question candidates were required to investigate how the characteristics of a circuit vary with its resistance.

Successful collection of data

(b)

(iii) The majority of candidates correctly recorded a value of I and V, within the allowed range, and with appropriate units. Other candidates needed to include the correct units, or needed to take correct account of the scale setting of the digital meter, to gain credit.

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(c) Most candidates were able to set up the circuit correctly, without assistance, and collect six sets of values of I and V showing the correct trend (V decreasing as I decreases).

Range and distribution of marks

(c) Most candidates recorded a suitable range of values for I. A few candidates could have made better use of the available range of values, needing a difference of at least 0.3 mA between their maximum and minimum values in order to gain credit.

Presentation of data and observations

Table

(c) Many candidates were awarded credit for using the correct column headings. Other candidates needed to provide A^{-1} units for the $1/I$ column instead of A or no units (or V^{-1} for the $1/V$ column). Others needed to distinguish clearly between a quantity and its unit e.g. I/A. Almost all candidates gave the raw values of I and V to the same number of decimal places and many expressed the values of $1/V$ to the same number of significant figures as, or one more than, the raw value(s) of V gaining credit. The great majority of candidates calculated $1/V$ correctly.

Graph

(d)

(i) Candidates were required to plot a graph of $1/I$ against $1/V$. Candidates may gain credit for drawing appropriate axes, with labels and sensible scales. Candidates chose not to start at zero for both the $1/I$ and the $1/V$ axes so that the plotted points occupied more than half the graph grid in both directions, gaining credit. Many candidates can improve by checking that the first and last points, when plotted, extend over at least six large squares in the *y*-direction and four large squares in the *x*-direction.

Many candidates gained credit for plotting tabulated readings. Others needed to draw plotted points so that their diameter is equal to, or less than, half a small square and some candidates can improve by plotting the points to within an accuracy of half a small square.

(ii) Some candidates were able to draw an acceptable line of best fit through six trend points. Some candidates needed to rotate their lines to give a better fit or move their lines to give a better balance of points about the line. Others needed to draw a line of best fit that best represents all of their data and not choose a few points that lie on a line or, as is commonly seen, choosing the first and the last point to draw the line, regardless of the distribution of the other points. Some candidates drew a kinked line with two short lengths, and can improve by drawing the line of best fit with a continuous long ruler.

Analysis, conclusions and evaluation

Interpretation of graph

(d)

(iii) Many candidates used a suitably large triangle to calculate the gradient, gaining credit for their read-offs and substitution into $\Delta y/\Delta x$ to find the gradient. Other candidates needed to check that the read-offs used are within half a small square of the best fit line drawn, show their substitution clearly into $\Delta y/\Delta x$ (not $\Delta x/\Delta y$) and check that their triangle is large enough (the hypotenuse should be at least half the length of the line drawn) in order to gain credit.

Some candidates read off the *y*-intercept at $x = 0$ successfully, gaining credit. Others needed to check that the *x*-axis started with $x = 0$ (i.e. no false origin) before reading off the *y*-intercept from the graph. Many candidates substituted a read-off into $y=mx+c$ successfully to determine the *y*-intercept. Others needed to check the point they have chosen is actually on the line of best fit and not just in the table.

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Drawing conclusions

(e) Most candidates recognised that 3*R* was equal to the value of the gradient calculated in **(d)(iii)** and were awarded credit. Others tried to calculate *R* by first substituting values into the given equation and then solving simultaneous equations. No credit is given for this as the question specifically asks for the answer in **(d)(iii)** to be used to determine *R*. Some candidates obtained a value of *R* that was in range, with appropriate units. Others needed to include units with their answer or take account of the units used to measure *I* or *V* (usually mA or mV) in order to avoid power-of-ten errors in their final answers.

Question 2

In this question candidates were required to investigate how the motion of a metre rule balanced on a cylinder depends on the diameter of the cylinder.

Successful collection of data

(a) Most candidates measured successfully the thickness *t* of the metre rule using the vernier calipers, expressing their raw value(s), with an appropriate unit, to the nearest 0.1 mm or 0.01 mm. A few candidates measured the width of the ruler instead, or omitted units from their answer, or only expressed their answer to the nearest mm.

(b)

(i) Most candidates were able to record a value for the diameter of cylinder A successfully. Others recorded the circumference of the cylinder or omitted units from their answer.

(c)

(ii) Most candidates recorded repeat measurements of *T*, either by measuring the time for several oscillations once, or by measuring individual values of *T* and calculating the average value. Some candidates forgot to divide their time by the number of oscillations, or mis-read the number on the stop clock (answers of 0.01 s or less were common).

(e) Most candidates recorded a second value of *d* and *T* successfully.

Quality

(c) Most candidates found that the second value of *T* (for the larger diameter cylinder) was less than the first value (for the smaller cylinder), and were awarded credit.

Display of calculation and reasoning

(b)

(ii) Almost all candidates calculated *w* correctly. A few needed to take account of the different units used to express *t* and *d* (e.g. mm and cm) when calculating *w*.

(e) Almost all candidates were able to calculate a second value of *w* correctly.

(f)

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

Analysis, conclusions and evaluation

(f)

(ii) Few candidates compared the percentage difference in their values of *k*, linking this to a judgement of whether or not their results supported the given relationship by comparing this percentage difference with an experimental percentage uncertainty, either taken from **(d)** or estimated themselves. Candidates are encouraged to work out the percentage difference between the two *k* values and then make a judgement as to whether this is above or below what is expected. They should state what they think is a sensible limit for the percentage uncertainty for this particular experiment.

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Estimating uncertainties in *T*

(d) Most candidates were familiar with the equation used to calculate the percentage uncertainty. Many candidates needed to consider a realistic value for the uncertainty in the time measurement, taking into account factors such as the difficulty of judging exactly when an oscillation has been completed, rather than just using the precision of the stop clock (usually 0.01 s) as an indication of the absolute uncertainty.

Evaluation

(g) The key to this section is for candidates to identify genuine problems associated with setting up this experiment and in obtaining readings e.g. the *difficulty in judging when an oscillation is complete* or *having to use a ruler to measure the diameter of the larger cylinder*. Vague answers such as *the retort stand was not stable*, or *the ruler had systematic error* do not receive credit.

Candidates are encouraged to suggest <u>detailed</u> practical solutions that either improve technique or give more reliable data e.g. …*use a video <u>with a clock</u>/<u>timer</u> to record the oscillation and then play back slowly to identify the exact time the oscillation started and finished*. Candidates can improve their answers by stating the methods used for each solution. In doing this candidates should look at how each solution helps this particular experiment. Credit is not given for suggestions that should be carried out anyway, such as repeating measurements and calculating averages or avoiding parallax errors by looking at an instrument 'square on'.

Candidates are discouraged from changing the experiment to a different one. A table giving details of limitations and potential improvements can be found in the mark scheme, together with some answers that did not receive credit.

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PHYSICS

Paper 9702/32
Advanced Practical Skills 2

Key messages

- The skills tested in **Question 1** are listed in detail in Syllabus section 5.2. Candidates need experience of using the relevant measuring equipment, and must be able to present results and calculations clearly to score high marks.

- Candidates should aim to make graphical work user friendly and choose appropriate scales to make finding points and interpreting gradient read-offs easy. Candidates should be encouraged not to make the plots occupy the whole grid by using awkward scales. As long as the plots occupy half of the grid, it is possible for sensible scales to be used at all times.

- **Question 2** tests some of the same skills but it also requires discussion about the design of the experiment. Marks are available for explaining why some measurements have large uncertainties and for suggesting how these could be improved by using different measuring equipment or by changed procedures. There are not often many 'standard' answers – careful consideration of the individual experiment is needed.

General comments

Good answers in **Question 1** showed candidates had taken care in manipulating apparatus and taking accurate readings. They were skilled at plotting graphs and determining a gradient and intercept. It was necessary to recognise which terms in the equation of a straight line graph represented the gradient and the intercept.

Careful preparation of candidates by many Centres led to a high standard in the skills tested in this question. Good answers had graph plots lying close to a straight line trend because candidates had carefully adjusted the string and the masses before noting readings. If candidates had also chosen scales to ensure plots were spread out over more than half the graph grid, then drawing the best fit line and performing the calculations became straightforward.

Good answers to **Question 2** were characterised by relevant, detailed comments in the final section, especially by those candidates who had decided why it was difficult to take measurements with masses balanced on the rule.

Comments on specific questions

Question 1

Candidates investigated how the equilibrium position of a pivoted wooden strip changed as different masses were hung from a string which provided a horizontal force on the strip.

Successful collection of data

(a) Good answers showed candidates were able to set up and adjust the apparatus for themselves.

(b) Good answers showed the height of the nail was measured accurately. As they were using a metre rule with a millimetre scale, strong candidates gave the height to the nearest millimetre e.g. 0.554 m or 55.4 cm. Weaker answers recorded the height to the nearest centimetre e.g. 0.56 m or 56 cm (these needed to be written as 0.560 m or 56.0 cm).

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(c) Good answers showed adjustment to the pulley height until the string was parallel to the bench and a string height recorded which was less than the nail height.

Range and distribution of readings

(d) Excellent answers used a wide range of masses to give a large change in string height. The maximum mass available was 200 g so good answers used a maximum mass of 180 g or more.

Weaker answers only used mass values between 50 g and 100 g. Candidates need to ask themselves, 'which quantity am I changing?' and 'what is the smallest value and what is the largest value I could use?'

It was pleasing that the quality of the data (judged by the amount of scatter about a straight-line trend on the graph) was good for the majority of candidates, reflecting the good preparation Centres had given. Weaker answers showed the need for increased patience and accuracy when taking readings.

Presentation of data and observations

Table

(e) The majority of Centres had done well in teaching candidates how to present their raw readings clearly in a well-drawn table. Good answers had table headings which included suitable units. In weak answers the unit of m^2 and $1/(H–h)^2$ presented a challenge. Some did not show that if the mass is squared the unit should also be squared, so incorrectly gave m^2/g rather than m^2/g^2. Weak answers also often did not give the unit for the whole quantity:

$\frac{1}{(H-h)^2}$ (m^{-2}) is acceptable (although use of a solidus is preferred) whereas $\frac{1}{(H-h)^2(m^2)}$ is not.

Good answers calculated the values of $1/(H–h)^2$ correctly with an appropriate number of significant figures linked to the significant figures in the difference between the two heights. For example, $(H–h)$ = (66.8 - 59.6) = 7.2 which is to 2 s.f. so the value of $1/(H–h)^2$ could have been given as 0.019 (2sf) or 0.0193 (3sf). Weak answers gave the calculated value to 4 s.f.

Candidates should always be encouraged to write down the value and not record a fraction. If this is not done the plotted points cannot be checked, and neither can the number of significant figures used be checked.

In good answers the values of mass were recorded to the nearest gram e.g. 50 g, 100 g or 0.100 kg. Weak answers either added zeros onto the mass values, e.g. 100.0 g or, when converting to kilograms, forgot to include the zero to represent grams (so 50 g became 0.05 kg rather than 0.050 kg). Good answers had values of *h* all recorded to the same number of decimal places, i.e. to the nearest mm.

Graph

(f) The standard of graph work was usually high, again reflecting good preparation by Centres. Good answers showed candidates choosing to use scales based on 2, 4, 5 or 10 with plots spread over more than half the graph grid. Weak answers were characterised by awkward scales based on 3 or 6 or using fractions rather than values. Other weak answers used a scale where one of the plots lay off the printed grid or with plots compressed into a small portion of the graph grid. Although Examiners expect at least half the grid to be used in both directions, scales should enable intermediate points to be read directly (without having to use a calculator).

Plotting of points was usually accurate, though weak answers had points which were penalised for being very large dots. Candidates should be encouraged to use a fine pencil so that the points and the line are less than half a small square wide. In good answers all results in the table were plotted. Some weak answers had only 5 of 6 points plotted - here candidates had rushed and for example plotted the first two, glanced over the next and then plotted three more. It may help to suggest that candidates count their plots when they think they have finished.

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Good answers showed an appropriate straight line with a good balance of plots along the whole line. Weak answers often had too much rounding of values (probably to make the plotting easier) and this resulted in scattered points and poor quality on the graph. Another characteristic of weak answers was a line drawn with too many plots lying to one side of the line or where the line needed to be rotated to give a good fit to all points.

Analysis, conclusions and evaluation

Interpretation of graph

(f) In the best responses, candidates had been well prepared for finding the gradient and intercept of a straight line graph. For the gradient a large triangle was chosen (with a hypotenuse longer than half the length of the drawn line) and read-offs were accurately taken from points which lay on the line. Good answers used these read-offs correctly, showing the working clearly, before writing the calculated value of the gradient on the answer line. The intercept was correctly calculated by substituting read offs from a point which lay on the line into the equation $y = mx + c$. Some good answers showed that if the x-axis included the value $x = 0$, then the intercept could be directly read off from the graph.

Weak answers for the gradient used too small a triangle or chose table values for the points of the triangle when these did not lie on the line drawn. Weak answers also often incorrectly found $\Delta x/\Delta y$ or left the answer as a fraction rather than calculating a final value.

Some weak responses for the y-intercept chose to extend the line below the grid trying to estimate a read off - an inaccurate method. Others attempted to read off the intercept but overlooked the fact that the scale used for the x-axis did not begin at zero.

Drawing conclusions

(g) Good answers showed a clear understanding of how the values found for gradient and intercept in **(f)** related to constants a and b in the equation of **(g)**. Working in these answers showed that

$$a = \frac{\text{gradient value from (f)}}{\text{intercept value from (f)}} \text{ and } b = \text{intercept value from (f)}.$$

Weak responses showed new calculations (often using simultaneous equations) rather than using the previous values of gradient and intercept.

The best answers included the correct units. For a the correct unit was g^{-2} or kg^{-2}, whichever was appropriate, and for b the unit was cm^{-2} or m^{-2}. Weak answers showed either no attempt at units or incorrect units and this suggests that some candidates need practice in how to work out the units for the constants in an equation.

Question 2

In this question, candidates were asked to investigate the deflection of a metre rule when two masses were placed on it. The experiment demanded care, dexterity and patience. Good responses showed excellent preparation by Centres and the ability of candidates to rise to the challenge of the experiment. The best answers showed repeat readings after the masses had been removed and then replaced. The best candidates thought about difficulties during the experiment and this made answering **(g)** much more straightforward.

Successful collection and presentation of data

(a)

(ii) Many excellent answers showed candidates had followed the instructions and used the diagram in Fig. 2.1 so the calculation of y was straightforward.

(iii) Good answers gave h to the nearest millimetre with a unit e.g. 5.8 cm. Weak answers gave h to the nearest centimetre (e.g. 6 cm) or added an extra zero (e.g. 5.80 cm) or did not write down the unit. Candidates should be encouraged to look on the answer line and, if there is no unit, think 'what is the unit of the quantity I am measuring?' and then to write its unit

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down. Here candidates used a rule with graduations to the nearest mm so their measurement should have been recorded to the nearest mm.

(b)

(ii)(iii) The best answers showed repeat readings clearly noted, with the average calculated and the correct unit on the answer line. Weak answers were characterised by a single value and some had no unit shown.

(c)

(i) Good answers correctly calculated *d*.

(d)(e) Good answers showed candidates had rearranged the apparatus correctly with a smaller separation of the supports producing a smaller measured deflection. For many, the change in the deflection was small but the best answers showed the correct trend.

Estimating uncertainties

(c)

(ii) Good answers calculated the percentage uncertainty by looking directly at the *d* value and choosing an estimate of the absolute uncertainty of 1 or 2 mm - this gave a large value for the percentage uncertainty. Weak answers tried to find the uncertainty in each value of *h* and add the two together.

Display of calculation and reasoning

(f)

(i) Good answers showed clear working and correctly calculated two values of *k*. Weak answers showed errors in rearranging the equation, and so calculated 1/*k* rather than *k*.

Analysis and conclusion

(f)

(ii) In assessing the validity of the relationship (by comparing the *k* values) good answers calculated the percentage difference between the two values of *k* (to 3 s.f.), then compared this to a criterion chosen and stated in their answer (e.g. 20%). If their calculated percentage difference was less than their chosen 20%, these answers carried on to say the results supported the suggested relationship. Other good answers would say that the relationship was not supported if their calculated percentage difference was greater than their 20% criterion. The strongest answers were where the calculated experimental percentage uncertainty from **(c)** was used as the criterion (rather than an arbitrary estimate such as 20% in the examples above).

Weak answers were too vague. Commonly the percentage difference was not found and the answer stated 'the difference is small' or '*k* values are not the same'. Other weak answers would round the *k* values to 1 or 2 s.f. to make them appear equal, whereas the *k* values in good answers were found to 3 s.f. and then compared.

Evaluation

(g) Many candidates identified relevant limitations and improvements. The best answers were characterised by detailed suggestions specific to <u>this</u> experiment where the masses only produced a small deflection of the rule. Weaker answers were characterised by general ideas which were too vague such as 'zero errors', 'systematic errors' or 'parallax errors' or statements with no link to the experiment. In this static experiment parallax errors were not relevant - candidates had time to move their heads into the correct position to take readings, to bend down and get close, and there was nothing to prevent the rule being held near to the apparatus when *h* was measured. Weak answers suggested taking photographs or videoing the experiment, but neither was relevant here.

Many good answers were characterised by including the suggestion that 'too few readings were taken'. The improvement given in good answers was 'take more readings with a wider variety of *y* values and plot a graph'. Weak responses had 'take more readings' (which could have meant 'take

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repeats') or 'take many readings and find the average'. Weak responses also did not mention plotting a graph.

Good answers picked up on the idea that the deflection produced is only small and stated this as a limitation, with the suggested improvement that a larger mass could be used. Weak answers sometimes pointed out the deflection was small but the solution was to use 'a more flexible rule' - this is not an acceptable improvement as the experiment was to investigate the rule provided.

Following on from the deflection being small, good answers recognised that the distance h was difficult to measure precisely as the rule was marked in mm. The good answers suggested an improvement would be to use a vernier caliper or a travelling microscope to measure h. Weak answers which identified this limitation would give the vague 'use a more precise instrument' as the improvement.

Good answers recognised that the physical size of the masses presented a challenge. A good answer may have stated 'the masses placed on the rule covered the scale marks; this made it difficult to read the distance between the end of the rule and the centre of the mass, so x was imprecise'. Weak answers would say 'the masses were large' or 'it was difficult to measure x'. For the improvement a good answer would suggest 'hang the masses from the rule using string' whereas a weak answer would give 'use transparent masses' or 'narrower masses'.

The published mark scheme gives further examples of creditworthy responses.

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PHYSICS

Paper 9702/33
Advanced Practical Skills 1

Key messages

- The skills tested in **Question 1** are listed in detail in Syllabus section 5.2. Candidates need experience of using the relevant measuring equipment, and must be able to present results and calculations clearly to score high marks.
- Candidates should aim to make graphical work user friendly and choose appropriate scales to make finding points and interpreting gradient read-offs easy. Candidates should be encouraged not to make the plots occupy the whole grid by using awkward scales. As long as the plots occupy half of the grid, it is possible for sensible scales to be used at all times.
- **Question 2** tests some of the same skills but it also requires discussion about the design of the experiment. Marks are available for explaining why some measurements have large uncertainties and for suggesting how these could be improved by using different measuring equipment or by changed procedures. There are not often many 'standard' answers – careful consideration of the individual experiment is needed.

General comments

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

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

Candidates did not seem to be short of time and both questions were attempted. Most candidates were confident in the generation and handling of data and their responses to the critical evaluation of their own experiment skills has improved. Candidates can improve their written answers by stating the read-offs used for the gradient calculation or showing the substitution used for the calculation for the *y*-intercept where there is a false origin or showing the percentage ratio calculation needed to find the percentage uncertainty instead of only writing a bald number on the answer line without any working.

There were no common misinterpretations of the rubric.

Comments on specific questions

Question 1

In this question candidates were required to investigate how the motion of a paper strip depends on its width.

Successful collection of data

(a)

(i) Most candidates were able to measure *x*, the width of the thin strip.

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(b)

(ii) Most candidates were able to measure *T* in range with a consistent unit. In a minority of cases the value of *T* was too small, indicating that half a complete swing was taken instead of a full swing. Many candidates timed several complete swings and hence calculated the time for one swing. A minority of candidates seemed to have the paper swing in simple pendulum mode instead of twisting it and then releasing it.

(c) Most candidates were able to set up the apparatus and tabulate six sets of values for *x* and *T* gaining credit for this section.

Range and distribution of marks

(c) Many candidates used a range of *x* to include 1 cm and 6 cm. Some candidates started at 2 cm and continued on above 6 cm and so did not gain credit.

Presentation of data and observations

Table

(c) Many candidates were able to include correct units with the column headings including 1/*x* (cm^{-1}). Some candidates wrote 1/*x* (cm) or 1/ *x*(cm) and this did not gain credit as the unit should be for the whole column heading, not a part of it. Many candidates stated the raw values of *x* to the nearest mm gaining credit. Some candidates gave *x* to the nearest cm only which did not gain credit as the ruler could be read to the nearest mm. A few candidates stated *x* to a tenth of a mm suggesting that these candidates were adding zeros for the sake of it and did not receive credit.

Many candidates were able to state the significant figures (s.f.) in the calculated quantity 1/*x* to the same as or one more than the number used for the corresponding value of *x*. The number of significant figures in the calculated quantity does not necessarily have to be the same down the column but must relate back to the raw data and so should be checked row by row. Those candidates who stated the raw data to the nearest cm (1 s.f.) often lost out on credit for significant figures if they quoted 1/*x* to 3 s.f.

The majority of candidates were able to calculate 1/*x* correctly. A few candidates rounded 1/*x* = 0.167 (for *x* = 6.0 cm) to 0.1 which did not gain credit. Small rounding errors e.g. 1/*x* = 0.16 were acceptable.

Graph

(d)

(i) Most candidates were able to plot a graph of *T* against 1/*x*. Some weak candidates left 1/*x* in the fraction form and tried to produce a graph scale on that basis. These candidates ended up with a non-linear scale. Many candidates used sensible scales making plotting or read-offs of the gradient points relatively easy. That said, there were candidates who drew awkward scales (1:3) leading to problems later on. Some candidates plotted ‘points’ that were greater than half a small square in diameter. Several candidates plotted points more than half a small square out from the correct position.

(ii) Many candidates were able to draw an acceptable line of best fit from all of their points plotted. Some lines could be rotated round to give a better fit and some lines were clearly drawn with two short lengths of ruler leading to a kink at the join. There was a reasonable allowance for scatter in order to gain credit for the quality mark and many candidates were credited here. Some candidates plotted a point off the grid area and so could not be awarded credit.

Analysis, conclusions and evaluation

Interpretation of graph

(d)

(iii) Most candidates used a suitably large triangle to calculate the gradient (the hypotenuse should be at least half the length of the line drawn). Some candidates need to check that the read-offs used are within half a small square of the best fit line drawn, show their substitution clearly into $\Delta y/\Delta x$ and not $\Delta x/\Delta y$ and check that their triangle is large enough (the hypotenuse should be at least half the length of the line drawn) in order to gain credit.

Some candidates read off the *y*-intercept at $x = 0$ successfully gaining credit. However a few candidates did not check that the *x*-axis started at $x = 0$ before reading off the *y*-intercept. Many candidates substituted into $y=mx+c$ successfully to determine the *y*-intercept. When using this method the point used must lie on the line of best fit and not just be taken from the table.

Drawing conclusions

(e) Many candidates were able to give the values of *a* and *b* with consistent units and using the correct method i.e. gradient = *a* and *y*-intercept = *b* with gradient and intercept values taken from **(d)(iii)** and were awarded full credit. If candidates obtain the values of *a* and *b* by substituting the values of points into the equation they will not gain credit. Other candidates would do well to include a unit consistent with their working. Often units were completely omitted although asked for in the question.

(f) Many candidates were able to identify a problem when determining an experimental value of *T* for $x = 15$ cm, that the time was too small or the clips were too narrow to hold the wider paper.

Question 2

In this question, candidates were required to investigate how the deflection of a metre rule supported near its ends, with a mass hanging from the centre, depends on the distance between the supports.

Successful collection of data

(a)

(ii) Many candidates measured distance l to the nearest cm instead of to the nearest mm and so did not gain credit. (The metre rule reads to the nearest mm.)

(iii) Many candidates were able to measure h_0 to the nearest mm. Some candidates missed the units and so did not receive credit.

(b)

(ii) Many candidates correctly recorded *h* to be less than h_0.

(e) The majority of candidates were able to obtain second readings of l, h_0 and *h* for the shorter support length.

Quality

(b)

(iii) Most candidates found that the deflection *d* was larger for the longer support length.

Presentation of data and observations

Display of calculation and reasoning

(b)

(iii) Many candidates successfully calculated the value of *d.*

(e)

(i) Many candidates were able to calculate *k* for the two sets of data.

(iii) Very few candidates related the significant figures for *k* to the significant figures in all the raw values used in calculating *k.* i.e. l and *d* or $(h_0 - h)$. Many candidates related to l^3 instead of l and to *h* and/or h_0 instead of *d* or $(h_0 - h)$. Reference to h_0 and/or *h* was not accepted as for example there were three significant figures in h_0 (39.9 cm) or *h* (36.8 cm), when $(h_0 - h)$ would be accurate to only two significant figures (3.1 cm): a third significant figure in this case i.e. 3.10 would be meaningless as the rule cannot read to 0.01 cm. Very weak

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candidates stated '3 SF because *k* is small' without any justification for the number of significant figures used.

Analysis, conclusions and evaluation

(e)

(ii) A minority of candidates compared their values of *k* using a percentage difference and linked this to a judgement of whether or not their results supported the given relationship by comparing this percentage difference with an experimental percentage error either taken from **(c)(ii)** or estimated themselves. Candidates are encouraged to work out the percentage difference between the two *k* values and then make a judgement whether this is above or below what is expected for this particular experiment. Candidates are encouraged to state what they think is a sensible limit for the percentage uncertainty for this particular experiment.

Estimating uncertainties in *d*

(c) Many candidates stated the correct ratio idea (×100) for working out the percentage uncertainty gaining credit. Some candidates need to consider a realistic uncertainty in the length measurement given that the measurement is stationary (i.e. 1 – 2 mm) in order to gain full credit for this section.

Evaluation

(f) The quality of written answers has improved with many candidates being awarded at least partial credit. Candidates are now more likely to look at the experiment and state what problems they had and offer some solutions. The key to this section is for candidates to identify real problems associated with setting up this experiment (e.g. difficult to measure height because the hanging mass is in the way) and in obtaining the readings. For example 'parallax error' on its own does not warrant credit but stating 'parallax error in measuring *h*' does warrant credit. For example the ruler was not clamped so it was difficult to ensure that it was vertical when reading *h.* Candidates were expected to carry out the experiment with due care and attention. Responses such as 'the support blocks fell over' do not gain credit, but the observation that 'the prism slipped relative to the block or the ruler' showed that this was a genuine problem with the experiment and so did gain credit. Fixing the prism to the support somehow would improve the experiment and therefore gained credit, but some candidates suggested sticking the ruler onto the prism – which would have changed the experiment irreparably, so did not gain credit.

Candidates can improve their written answers by stating the practical method used for each solution that either improves the technique or gives more reliable data. In doing this candidates should look at how each solution helps this particular experiment (e.g. the deflection was very small so increase the value of the mass in order to increase the deflection). Candidates are encouraged to steer away from changing the experiment to a different one (e.g. test for different masses). Candidates are also encouraged to steer away from what they should already be doing throughout the experiment (e.g. repeat readings to determine the deflection). The use of the set square as a solution was not enough to gain credit in the solution section without detailed description or a drawing showing how the set square was used either to maintain the rule vertical or for the read-off for the height.

A comprehensive list of problems and solutions can be found in the mark scheme.

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PHYSICS

Paper 9702/34
Advanced Practical Skills 2

Key messages

- The skills tested in **Question 1** are listed in detail in Syllabus section 5.2. Candidates need experience of using the relevant measuring equipment, and must be able to present results and calculations clearly to score high marks.

- Candidates should aim to make graphical work user friendly and choose appropriate scales to make finding points and interpreting gradient read-offs easy. Candidates should be encouraged not to make the plots occupy the whole grid by using awkward scales. As long as the plots occupy half of the grid, it is possible for sensible scales to be used at all times.

- **Question 2** tests some of the same skills but it also requires discussion about the design of the experiment. Marks are available for explaining why some measurements have large uncertainties and for suggesting how these could be improved by using different measuring equipment or by changed procedures. There are not often many 'standard' answers – careful consideration of the individual experiment is needed.

General comments

There were few problems with providing the necessary apparatus.

Candidates had time to complete both questions, and in most cases the instructions were understood and followed carefully. There was variation between Centres, but most candidates knew how to use the measuring equipment and could present data in tables and graphs. This led to a generally good performance in **Question 1** and in the earlier sections of **Question 2**. The discussion section at the end of **Question 2** was weaker, with few candidates giving many answers that were both relevant and sufficiently detailed.

Comments on specific questions

Question 1

In this question candidates were required to investigate the equilibrium position of a beaker rolling on horizontal rails.

Successful collection of data

(c)(d) Most candidates recorded sensible values for the first two angular positions of the beaker, with only a few omitting the unit.

(e) Nearly all candidates successfully recorded results for six different masses attached to the circumference of the beaker. Although the instruction asked for each new angular position *y*, a surprising number did not record it – this meant that neither consistency nor calculations could be checked and so credit could not be awarded.

Angles were measured using a protractor and most candidates correctly recorded all their values to the nearest degree (e.g. 87°), with only a minority wrongly adding an extra zero to their values (e.g. 31.0°). Masses were usually recorded to the nearest gram but where they had been converted to kilogram this precision was sometimes dropped (e.g. 0.17 kg rather than 0.170 kg).

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(g) For the beaker measurement many candidates recorded the diameter rather than the radius.

Range and distribution of values

(e) Masses up to 210 g were available and many candidates gained credit for using a substantial part of this range. Some candidates appeared to have been provided with more than the specified number of masses.

Presentation of data and observations

Table

(e) Candidates had been well prepared in the presentation of results and tables were generally neat and clear. Several candidates had difficulty including the unit in headings for angles. There should be some sort of distinguishing mark between the quantity and the unit, so y/° or y(°) was acceptable but y° was not.

The number of significant figures for $\sin\theta$ was well chosen in most cases.

Graph

(f) Graphs were generally of a high standard. Most scales were chosen to utilise at least half the length of each axis, but candidates from some Centres used very awkward scales in an attempt to fill the grid completely. It should be easy to plot points and read off intermediate values without having to use a calculator.

Plotting was usually clear and accurate, but errors were more common where scales were awkward.

The quality of results (as indicated by scatter on the graph) was very good in most cases.

Analysis, conclusions and evaluation

Interpretation of graph

(g) Nearly every candidate knew how to find the gradient of their graph, and the only errors were in using too small a triangle or mis-reading coordinates. The y-intercept could often be read directly from the graph if there was no false origin, but most candidates chose to calculate it, usually successfully.

Drawing conclusions

(h) The stronger candidates compared their graph with the equation relating m and θ and then correctly equated their gradient to r/a and used this to find the constant a. Many went on to find the correct unit, though a common error was to include degrees.

Question 2

In this question, candidates were required to investigate the motion of a mass hanger suspended from a rubber band.

Successful collection of data

(a) Candidates were asked to determine the hanger radius and were expected to measure the diameter to achieve this (additional credit was given for showing the working). Nearly all recorded an acceptable value for R, although clear evidence that the diameter had been measured was less common.

(b) Most candidates recorded a sensible time for the oscillation, and many gained extra credit for repeating their readings (or for deriving their value from a time for several oscillations).

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Some candidates recorded very small times (less than 0.01 s) and it seems likely that they were unfamiliar with the stopwatch display. Centres should ensure that candidates can use equipment correctly before the practical exam.

(d) Most candidates gained full credit for the readings taken for the second mass hanger.

Estimating uncertainties

(a) This was generally done well.

Presentation of data and observations

Display of calculation and reasoning

(c)(d) A high standard was evident in all these calculations, with the only common error being in the unit for the quantity *C* (some candidates converted cm to m or g to kg in the calculation but not correctly in the unit).

(e) Calculation of the two values of *k* was generally well done.

Conclusions

(e) Most candidates knew that they had to compare their two values for the 'constant' *k* to come to a conclusion. To gain credit the percentage difference between the two *k* values had to be compared with a tolerance before deciding whether the suggested relationship could be valid. The candidate was expected to state a tolerance (e.g. '20%' or 'the experimental uncertainty in **(a)(iii)**'), and candidates from some Centres did this well. Many others calculated the percentage difference but did not go any further, and some considered only the absolute difference rather than the percentage difference.

Evaluation

(f) The weaker answers tended to lack relevance to the actual investigation undertaken (problems such as air conditioning fans and parallax were not significant in this experiment). To gain credit, an improvement had to involve a change that could not have been made using the equipment provided.

Three quantities were involved in this experiment: mass, radius and time. Each of these could have been considered and problems in their measurement identified:

Mass: Were the values given on the actual masses accurate? Should they be checked? How could they be checked?
Radius: How could the precision of this measurement be improved by using a different method to find the diameter?
Time: Was there a problem in judging the start and end of an oscillation? How could this be improved?

(i) The most common difficulties to be identified were 'two values of *k* are not enough to evaluate the relationship', and 'it was difficult to judge the point at which to start and stop the timing'.

(ii) Many candidates' ideas for improvements were along the right lines but did not give enough practical detail ('measure the radius more accurately' is too vague, but 'use a vernier caliper to measure the diameter' is worthy of credit). The more able candidates thought about increasing the time of an oscillation (e.g. by increasing the mass).

The published mark scheme shows the other responses that were accepted.

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PHYSICS

Paper 9702/35
Advanced Practical Skills 1

Key messages

- The skills tested in **Question 1** are listed in detail in Syllabus section 5.2. Candidates need experience of using the relevant measuring equipment, and must be able to present results and calculations clearly to score high marks.

- Candidates should aim to make graphical work user friendly and choose appropriate scales to make finding points and interpreting gradient read-offs easy. Candidates should be encouraged not to make the plots occupy the whole grid by using awkward scales. As long as the plots occupy half of the grid, it is possible for sensible scales to be used at all times.

- **Question 2** tests some of the same skills but it also requires discussion about the design of the experiment. Marks are available for explaining why some measurements have large uncertainties and for suggesting how these could be improved by using different measuring equipment or by changed procedures. There are not often many 'standard' answers – careful consideration of the individual experiment is needed.

General comments

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

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

Candidates did not seem to be short of time and both questions were attempted. Most candidates were confident in the generation and handling of data and their responses to the critical evaluation of their own experiment skills has improved. Candidates can improve their written answers by stating the read-offs used for the gradient calculation or showing the substitution used for the calculation for the *y*-intercept where there is a false origin or showing the percentage ratio calculation needed to find the percentage uncertainty instead of only writing a bald number on the answer line without any working.

There were no common misinterpretations of the rubric.

Comments on specific questions

Question 1

In this question candidates were required to investigate how the motion of two pendulum bobs depends on the tension in a spring connecting them.

Successful collection of data

(a) Candidates were able to measure l_0, the length of the coiled part of the spring.

(b)

(iv) Most candidates were able to measure T in range with a consistent unit. In a minority of cases the value of T was too small indicating that half a complete swing was taken instead

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of a full swing. Many candidates timed several complete swings and hence calculated the time for one swing.

(c) Most candidates were able to set up the apparatus and tabulate six sets of values for *x* and *T* gaining credit for this section.

Range and distribution of marks

(c) Many candidates used a range of *x* equal to or greater than 7 cm. Some candidates started at 2 cm and continued every cm until 7 cm and so were not awarded credit.

Presentation of data and observations

Table

(c) Many candidates were able to include correct units with the column headings. Some candidates wrote *x* cm and this did not gain credit as the column heading and the unit are not separated by a distinguishing mark. Some candidates gave l to the nearest cm only which did not receive credit as the ruler could be read to the nearest mm. A few candidates stated l to a tenth of a mm suggesting that these candidates were adding zeros for the sake of it and were not awarded credit.

Many candidates were able to state the precision in the calculated quantity *x* from the precision used in the values of l_0 and l. The number of significant figures in the calculated quantity does not necessarily have to be the same down the column but must relate back to the raw data and so should be checked row by row. Those candidates who stated the raw data to the nearest cm (1 s.f.) often were not awarded credit for significant figures if they quoted *x* to 3 s.f.

The majority of candidates were able to calculate *x* correctly.

Graph

(d)

(i) Candidates were able to plot a graph of *T* against *x*. Many candidates used sensible scales making plotting or read offs of the gradient points relatively easy. That said, there were candidates who drew awkward scales (1:3) leading to problems later on. Some candidates plotted 'points' that were greater than half a small square in diameter. Several candidates plotted points more than half a small square out from the correct position.

(ii) Many candidates were able to draw an acceptable line of best fit from all of their points plotted. Some lines could be rotated round to give a better fit and some lines were clearly drawn with two short lengths of ruler leading to a kink at the join. There was a reasonable allowance for scatter in order to gain credit for the quality mark and many candidates gained credit here. Some candidates plotted a point off the grid area and so could not be awarded credit.

Analysis, conclusions and evaluation

Interpretation of graph

(d)

(iii) Most candidates used a suitably large triangle to calculate the gradient (the hypotenuse should be at least half the length of the line drawn). Some candidates need to check that the read-offs used are within half a small square of the best fit line drawn, show their substitution clearly into $\Delta y/\Delta x$ and not $\Delta x/\Delta y$ and check that their triangle is large enough (the hypotenuse should be at least half the length of the line drawn) in order to gain credit.

Some candidates read off the *y*-intercept at $x = 0$ successfully gaining credit. However a few candidates did not check that the *x*-axis started at $x = 0$ before reading off the *y*-intercept. Many candidates substituted into $y=mx+c$ successfully to determine the *y*-intercept. When using this method the point used must lie on the line of best fit and not just be taken from the table.

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Drawing conclusions

(e) Many candidates were able to give the values of *p* and *q* with consistent units and using the correct method i.e. gradient = *p* and *y*-intercept = *q* with gradient and intercept values taken from **(d)(iii)** and were awarded full credit. If candidates obtain the values of *p* and *q* by substituting the values of points into the equation they will not gain credit. Other candidates would do well to include a unit consistent with their working. Often units were completely omitted although asked for in the question.

(f) Most candidates were able to calculate *x* when *T* = 75 s using consistent units.

Question 2

In this question, candidates were required to investigate how the distance that a rod moves into the sand when a mass is dropped onto it depends on the rod's thickness.

Successful collection of data

(a) Many candidates were able to measure the diameter to the nearest 0.01 mm and take repeat readings along the rod's length. Some candidates measured the diameter *d* to the nearest mm or they did not show written evidence that they had repeated their measurements and so did not gain credit.

(c)

(ii) Many candidates were able to measure *h* with consistent units although some candidates missed out the units.

(d)

(ii) Many candidates correctly recorded *x* to the nearest mm and consistent units.

(f) The majority of candidates were able to obtain second readings of *d* and *x* for the thinner rod.

Quality

(f)

(ii) Most candidates found that the value of *y* was larger for the thinner rod gaining credit.

Presentation of data and observations

Display of calculation and reasoning

(d)

(iii) Many candidates successfully calculated the value of *y.*

(g)

(i) Many candidates were able to calculate *k* for the two sets of data.

(iii) Very few candidates related the significant figures for *k* to the significant figures in all the raw values used in calculating *k*, i.e. *d* <u>and</u> *y* or *x.* Many candidates related to d^2 instead of *d.* Very weak candidates stated '3 SF because *k* is small' without any justification for the number of significant figures used.

Analysis, conclusions and evaluation

(g)

(ii) A minority of candidates compared their values of *k* using a percentage difference and linked this to a judgement of whether or not their results supported the given relationship by comparing this percentage difference with an experimental percentage error either taken from **(c)(ii)** or estimated themselves. Candidates are encouraged to work out the percentage difference between the two *k* values and then make a judgement whether this is above or below what is expected for this particular experiment. Candidates are encouraged to state what they think is a sensible limit for the percentage uncertainty for this particular experiment.

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Estimating uncertainties in *y*

(e) Many candidates stated the correct ratio idea (×100) for working out the percentage uncertainty gaining credit. Some candidates need to consider a realistic uncertainty in the length measurement given that the measurement is inconsistent as the rod leans to the side (i.e. 2 – 5 mm) in order to gain full credit for this section.

Evaluation

(h) The quality of written answers has improved with many candidates being awarded at least partial credit here. Candidates are now more likely to look at the experiment and state what problems they had and offer some solutions. The key to this section is for candidates to identify real problems associated with setting up this experiment (e.g. it was difficult to see if the mass is directly above the rod) and in obtaining the readings (e.g. difficult to measure *x* accurately with their finger).

Candidates can improve their written answers by stating the practical method used for each solution that either improves the technique (e.g. mark a line on the rod) or gives more reliable data. In doing this, candidates should look at how each solution helps this particular experiment (e.g. the depth *x* was very small so increase the value of the mass or height). Candidates are encouraged to steer away from changing the experiment to a different one (e.g. test for different masses). Candidates are also encouraged to steer away from what they should already be doing throughout the experiment (e.g. repeat readings in measuring the diameter).

A comprehensive list of problems and solutions can be found in the mark scheme.

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PHYSICS

Paper 9702/41

A2 Structured Questions

Key messages

- As always, candidates should be encouraged to read each question carefully before answering, paying particular attention to command words such as 'state' or 'explain' which each require different types of response.

- Many candidates would benefit from taking a moment to consider the numerical answers that they have obtained, especially as regards powers of ten. A quick check on whether an answer is 'reasonable' would allow candidates to detect errors in their working.

- Candidates should be encouraged not to 'round off' answers at intermediate stages of a calculation, as this can lead to inaccurate and inappropriate final answers.

- Candidates should be advised to use the data given on page 2 of the question paper. In particular, the use of the approximation $g = 10\,\text{m}\,\text{s}^{-2}$ should be discouraged.

General Comments

Candidates can improve on their answers to **Section B** by deepening their understanding of the topics in the 'Applications of Physics' section of the syllabus.

Candidates should be encouraged to give a greater level of explanation of their work. In particular, they should be advised to give the algebraic expressions that they intend to use in any calculation, rather than merely writing down the numerical values of the data.

Candidates should appreciate that if a question asks for a statement with an explanation then, for the award of credit, the explanation is essential.

Comments on Specific Questions

Section A

Question 1

(a)

(i) There were many good answers. A common error was to refer vaguely to 'distance' rather than the 'distance between masses'. Candidates who attempted to state the law by reference to an equation needed to explain all the symbols used.

(ii) Candidates should realise that Newton's law of gravitation applies because the diameters of a planet and the Sun are very much less than the distance between them.

(b)

(i) The similarity was sometimes stated to be an 'inverse square law', but without making it clear what quantity follows this law.

(ii) With few exceptions, a correct answer was given. Most candidates identified that gravitational force is always attractive, while electric force can be attractive or repulsive.

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Question 2

(a) Candidates needed to refer to the number of atoms in 12 g of carbon-12. It was insufficient to simply quote a numerical value of the Avogadro constant or to refer to particles instead of atoms.

(b) A correct answer could be achieved by using either $pV = nRT$ or $pV = NkT$. Those that used $pV = nRT$ sometimes confused the amount of substance with the number of atoms. The vast majority of the answers correctly converted the units of the temperature from degrees Celsius to kelvin.

Question 3

(a) It is important that definitions are stated precisely in order to avoid ambiguity. Reference should be made to 'displacement' rather than 'distance'.

(b)

(i) Many candidates realised that $A\rho g/m$ is a constant and so the acceleration must be proportional to the displacement. The significance of the minus sign was less well understood. This shows that the acceleration acts in the opposite direction to the displacement and is always towards a fixed point.

(ii) This part of the question was generally well answered. A common error was not converting the area of cross-section from units of cm^2 to m^2.

Question 4

(a) Candidates needed to give a comprehensive definition. Many omitted either 'unit' or 'positive' from their description of the charge.

(b)

(i) In most answers, the magnitude of the electric field strength was correctly stated to be equal to the potential gradient. Some candidates attempted to express this relationship as an equation. Candidates should be encouraged to explain all symbols that they use.

(ii) Many candidates correctly explained that the force on particle Q is proportional to the electric field strength. It was then necessary to explain the relationship between the electric field strength and the gradient of the curve. Few candidates appreciated that the gradient of the curve was proportional to the electric potential gradient.

(c) Although there were some well-explained calculations, a common mistake was to confuse electric potential energy with electric potential.

(d)

(i) Most answers were mere statements of the sign of the charges without any valid supportive reasoning. Candidates needed to explain how work is got out as the charge separation decreases (or *vice versa*) and so the charges must have opposite signs.

(ii) Many candidates appreciated that doubling the charge on particle P would result in the graph having an increased gradient, although it was seldom explained that this was due to the doubling of the potential energy at a given separation.

Question 5

(a) There were many good answers. Some referred to the force on a charge, without making it clear that the force is experienced only when the charge is moving.

(b)

(i) While some candidates realised that the force on the particle is always normal to the direction of its travel, only a few mentioned that the speed of the particle remains constant. Weaker candidates sometimes confused the magnetic field with a uniform electric field and referred to a constant downward force or a parabolic path.

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(ii) Most answers simply equated the centripetal force to the magnetic force. This gives the impression that there is an equilibrium situation and so candidates need to explain that the centripetal force is provided by the magnetic force.

(c)

(i) Many candidates appeared to guess the direction of travel. The charged particle loses kinetic energy as it passes through the foil, which causes a reduction in the radius of its path.

(ii) Generally, it was appreciated that the ratio of the momenta is equal to the ratio of the radii. However, some candidates inverted the correct ratio or gave a ratio that was not consistent with the direction of travel indicated in **(i)**.

Question 6

(a)

(i) Candidates need to understand that the coils are wound on a core made of iron in order to concentrate the flux and reduce the flux losses.

(ii) While many answers referred to current in the core producing heating, few made it clear that this current is induced because of the changing flux in the core. A common misconception was that all the heat energy in the core had been conducted into it from the transformer coils.

(b)

(i) Faraday's law of electromagnetic induction was correctly quoted by the vast majority of candidates.

(ii) There is a phase difference because the magnetic flux is in phase with the e.m.f. across the primary coil, whereas the potential difference across the load is proportional to the rate of change of flux. The question asked for an explanation that uses Faraday's law and so explanations that used Lenz's law were not awarded any credit. One misconception was that the phase difference was caused by the primary coil having a different number of turns to the secondary coil.

(c)

(i) It was generally appreciated that high voltages are used in order to reduce energy losses. It was expected that candidates would refer to lower current at higher voltage for the same power transmission. This lower current then results in lower energy losses in the transmission cables.

(ii) Only a minority of candidates appreciated that alternating current is used for transmission in order to allow the voltage to be changed easily and efficiently.

Question 7

(a) Most answers correctly mentioned that the wave theory of light predicts that electrons will always be emitted after a sufficiently long time delay. Candidates need to understand that the reason for this is that the wave theory predicts that the electron will collect energy continuously during the delay time. Many of the weaker candidates simply explained the photoelectric effect, which did not address the question being asked.

(b)

(i) No value is given for kinetic energy because the radiation wavelength of 650 nm is greater than the threshold wavelength.

(ii) The calculation was usually completed successfully. Candidates should be encouraged to write down the photoelectric equation before attempting any substitution. A common error was to express the equation with one of the terms showing the wrong sign. A small minority of candidates based their calculation on the false assumption that the threshold wavelength is 650 nm.

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(c)

(i) Many answers correctly stated that the maximum kinetic energy of the photoelectrons would be larger, but did not explain that this was due to the larger photon energy.

(ii) A widespread misconception was that the arrival rate of the photons would be unchanged because the intensity is unchanged. If each photon ‘carries’ more energy, then the rate of arrival of the photons must be lower in order to maintain the constant intensity. Thus, the rate of emission of photoelectrons would be reduced.

Question 8

(a) Candidates need to improve their understanding of the graph of binding energy per nucleon against nucleon number. Many had little appreciation as to how to locate the approximate positions of the given isotopes.

(b)

(i) In nuclear fission a ‘heavy’ nucleus is split into two ‘lighter’ nuclei of approximately equal mass. Candidates should use the correct terms in their statements. A nucleus should not be confused with an element, atom, nucleon or nuclide.

(ii) In order to provide a comprehensive answer, candidates needed to first explain what is meant by binding energy. It was then necessary to explain that nuclear fission is energetically possible because the binding energy of the parent nucleus is less than the sum of the binding energies of the two product nuclei.

Section B

Question 9

(a) When an operational amplifier is used as a comparator, it compares the <u>two potentials</u> at its inputs. Rarely did candidates state how this comparison determines the output of the comparator.

(b)

(i) The majority of answers gave a correct calculation.

(ii) Candidates need to improve their understanding of comparator circuits. When the temperature of the thermistor is between 5 ºC and 10 ºC the operational amplifier is saturated with an output of –9 V. Between 10 ºC and 20 ºC, the output is +9 V. Only a small minority of answers correctly identified that the output suddenly ‘switches’ at 10 ºC. It was important to link any comments about the input and output potentials to a corresponding temperature of the thermistor. A common misconception was that a gradual increase in the temperature of the thermistor caused a gradual increase in the output potential of the comparator.

Question 10

(a) This part of the question was generally well answered. A small minority of answers wrongly referred to the speed of light or the speed of the medium, rather than the speed of sound.

(b) Answers needed to be precise. It was important to explain that the intensity reflection coefficient is approximately equal to unity, rather than just ‘very large’. Similarly, candidates needed to make it clear that most of the ultrasound *intensity* is reflected.

(c)

(i) With few exceptions, a correct answer was given.

(ii) The majority of candidates were able to quote an expression for the exponential decrease of the intensity of the ultrasound but two common mistakes were evident. The first of these was not realising that the ultrasound travels a distance of $2x$, being attenuated on both of the ‘outward’ and ‘return’ journeys. The second error was not allowing for the decrease in the intensity of the ultrasound when reflection occurs at the boundary between fat and muscle.

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Question 11

(a) Generally, the answers to this part of the question were good.

(b) Candidates need to improve their understanding of frequency modulation. In **(i)**, the amplitude of the carrier wave was sometimes confused with the amplitude of the information signal. In **(ii)** to **(iv)**, many candidates did not have a quantitative understanding of the variation of the carrier wave frequency.

Question 12

(a) The copper braid provides electromagnetic shielding of the inner copper wire from external noise so that there is less interference of the signal that is being 'carried' by the cable. It also acts as a 'return' wire for the signal. Only a minority of answers understood the nature of the shielding and some incorrectly described thermal or mechanical shielding.

(b) Most candidates were able to suggest two sensible reasons for the preferential use of a coaxial cable. It is important to appreciate that, although the amount of noise can be reduced by using a coaxial cable, it is not possible to eliminate it altogether. Candidates must ensure that they have a clear understanding of any terms that they use in their answer, such as 'bandwidth', 'noise' and 'attenuation'.

(c) This calculation caused few problems for well-prepared candidates. Others confused attenuation with gain. Candidates should practice using the attenuation formula to ensure that errors are avoided.

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PHYSICS

Paper 9702/42
A2 Structured Questions

Key messages

- As always, candidates should be encouraged to read each question carefully before answering, paying particular attention to command words such as 'state' or 'explain' which each require different types of response.
- Many candidates would benefit from taking a moment to consider the numerical answers that they have obtained, especially as regards powers of ten. A quick check on whether an answer is 'reasonable' would allow candidates to detect errors in their working.
- Candidates should be encouraged not to 'round off' answers at intermediate stages of a calculation, as this can lead to inaccurate and inappropriate final answers.
- Candidates should be advised to use the data given on page 2 of the question paper. In particular, the use of the approximation $g = 10\,\text{m}\,\text{s}^{-2}$ should be discouraged.

General comments

There were some excellent scripts where it was clear that the candidates were well-prepared for this examination. This was balanced by scripts where there was very little knowledge of the underlying physics and understanding of concepts was extremely weak.

It is expected that, in Paper 4, candidates will demonstrate the ability to apply the knowledge they have acquired during their studies. Consequently, a significant proportion of the credit available is awarded for the understanding and application of the physics principles.

The level of explanation, particularly of calculations, has shown some improvement. Candidates should be encouraged to give explanation since this allows for the award of credit for the correct approach to problems.

Candidates appeared to have sufficient time to complete their answers to the questions. There were comparatively few scripts where parts of questions had been left unanswered.

Comments on specific questions

Section A

Question 1

(a) Answered well by many candidates. This was meant to be a general statement as regards fields and most candidates correctly did not refer to one particular type of field.

(b) Frequently, the similarity was said to be an *inverse square law*. In this case, the question did refer to force but candidates should appreciate that force and potential are not both represented by the same function.

With few exceptions, this part of the question was answered successfully by reference to attractive and repulsive forces

(c) In general, where errors occurred, they were caused by incorrect substitution. In such questions, candidates should be advised to manipulate the equations in symbols before attempting any

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substitution. The use of the symbol k to represent $1/4\pi\varepsilon_0$ should be avoided. Candidates who used this symbol frequently substituted the Boltzmann constant into their equations.

Question 2

(a) By far, the most common answer was that it is the Avogadro number of atoms. This is not a definition. Candidates should realise that the mole is an amount of substance containing the same number of atoms/molecules as there are atoms in 12 g of carbon-12.

(b) The calculation presented very few difficulties. Candidates should be warned not to round off answers in the middle of calculations that have more than one part. In this instance, rounding off the values for the amount of gas in each vessel before summing could create an unacceptable answer for the total amount of substance.

Question 3

(a) This part of the question did cause some problems. Many answers were restricted to a comment that the charge would create a potential difference and that this is energy. Some candidates did discuss the fact that the charge separation would be associated with either energy stored or work done. Very few stated that the charges on the plates would be equal but opposite and, therefore, summing the charges would give a resultant of zero.

(b)

(i) The calculation itself was completed successfully by most candidates but there were many instances where the graph was read incorrectly.

(ii) In most scripts, the calculation was attempted by use of the formula $E = ½CV^2$, rather than using the area below the graph line of Fig. 3.2. Candidates should take care when using the formula. In some instances, the expression $E = ½C\Delta V^2$ was quoted. This lead to some using the expression correctly i.e. $\Delta V^2 = 10^2 - 7.5^2$ whilst others used $(10 - 7.5)^2$. A significant minority attempted to use the incorrect expression $E = ½\Delta Q\Delta V$.

(c) The usual procedure was to determine the total capacitance and then to multiply this by the total potential difference. Some did then give their answer as one half of this charge.

Question 4

(a) For a complete answer to this section, it was necessary to make reference to the direction of movement of energy. It was quite common to find that $+\Delta U$ was given as the change in internal energy although, by reference to $+q$ and to $+w$, they should have stated *increase*.

(b)

(i) Most answers did make reference to change of state, rather than specify either fusion or vaporisation. Candidates should be advised that, in definitions where a ratio is involved, then this aspect should be made clear. Reference should be made to *per unit mass* rather than either 'of a unit mass' or 'of 1 kilogram'.

(ii) Most answers were given little credit because the question had not been read carefully and, consequently, a comparison was not made between the two changes of state. For example, many candidates stated that the volume change on evaporation is very large but then did not mention volume change on melting. Likewise, the differences between the changes in the separation of molecules or the differences between the nature of the bonds was not discussed. Rather, a statement was made regarding one change of state.

Question 5

(a)

(i) Most statements were satisfactory.

(ii) It was expected that, in each part, reference would be made to the nature of the motion of the magnet and how this affects the rate of change of flux linkage. There were many good answers but a significant minority described only either the motion of the magnet or the rate of change of flux.

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(b) Completed successfully by nearly all candidates. The use of vulgar fractions in answers should be discouraged.

(c) Most sketches did indicate a peak in the correct position but the shape of the curve frequently lacked realism. Candidates should be advised to take more care as regards the shape of sketch curves, even to the extent of stressing that such curves are smooth.

(d) The shape of the curve was identified with resonance. Although many clear examples of resonance were provided, the mere statement of 'child on a swing' was not accepted. This was too vague in that resonance is not always invoked. Candidates should be aware of the fact that the damping system on a car is not an example of resonance.

Question 6

(a)

(i) The most common error here was in the rounding of the figures in the answer of 60.48 Hz. This should not be rounded to 61 Hz.

(ii) Answered correctly by most candidates.

(b) Candidates should be encouraged to quote relevant formulae before any substitution is carried out. The majority of errors were in those scripts where no formula was quoted.

Question 7

(a) In most scripts, the formula $\lambda = h/p$ was quoted and then the symbols *h* and *p* were explained. The question asked for a statement as to what is meant by the de Broglie wavelength. Consequently, this approach was not given credit. It was expected that candidates would state something to the effect that the de Broglie wavelength is the wavelength associated with a moving particle.

(b) The calculations were completed with little difficulty.

(c) Many answers involved a beam of electrons incident on a target giving rise to concentric rings on a screen. Unfortunately, experimental details were lacking. For example, the apparatus must be contained in an evacuated vessel, the target must be very thin (e.g. a carbon film), and the screen must be fluorescent. Finally, seldom was the diffraction pattern likened to that which could be obtained using light.

Question 8

(a) There was some confusion between the terms *nucleus, nucleon* and *nuclide.* Nuclear binding energy involves separating the nucleons of a nucleus to infinity.

(b) The most common error was to misquote the atomic mass unit as being 1.67×10^{-27} kg. This lead to an answer of 939 MeV which was, invariably, then assumed to be 930 MeV. Others did not show clearly how energy in joule is converted to energy in MeV.

(c) It was expected that candidates would determine the mass defect and then, in **(i)** they would multiply this defect by 930. In **(ii)**, they would multiply the defect by 930/97. Unfortunately, many did not calculate a mass defect, but instead used the total mass of one of the particles.

Section B

Question 9

(a) In many scripts, credit was given for the shape of the wire in the gauge but features such as the use of thin wire and enclosing the wire in 'plastic' were omitted. Many thought that the wire would be in a box.

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(i) In most answers, there was a reference to gain but equally, this could be the gain of the circuit, the open-loop gain or the gain of the op-amp.

(ii) There were many candidates who did not seem to realise that, for zero output, the two inputs must be at the same potential. Those who did understand this concept usually went on to complete the calculation.

(iii) In most scripts where **(ii)** had been completed successfully, then the correct answer was obtained for V_{OUT}.

Question 10

This is not the first occasion when a question similar to this has been asked. The general standard of the answers was much improved although there are significant numbers of candidates who make statements in the same paragraph that are relevant not only to NMR but also CT scanning and ultrasound diagnosis.

The main area of confusion was concerned with the time when the nuclei would de-excite with the emission of r.f. pulses. The use of the non-uniform field as a means of changing the location of detection was frequently omitted.

Question 11

(a) There seemed to be some doubt as to what was expected when the question asked for a statement and explanation. All too frequently, bandwidth was mentioned without mentioning information carrying capacity. Likewise, unreliable communication was stated without giving any reasoning for this. A popular misconception was that attenuation in the case of satellites is very much reduced.

(b) Most answers included the term *swamping* but its use was suspect. In many answers, both uplink and downlink signals were thought to be swamped. Rarely was it made clear that the uplink signal must be amplified greatly before transmission back to Earth and that it is this much amplified downlink signal that would swamp the much attenuated uplink signal. A popular misconception was that it is the frequencies that are swamped.

Question 12

(a)

(i) As is usual with this type of calculation, there were some very good answers. The number of candidates who appear not to appreciate the concepts has reduced markedly.

(ii) The most common error was to calculate the ratio of the input signal to the noise and then not deduct 24 dB before dividing by the attenuation per unit length.

(b) A suggestion related to less attenuation was given in many scripts. Some candidates thought that the wavelength of infra-red is shorter than that of ultraviolet radiation. Others gave health reasons as the explanation for the use of infra-red radiation.

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PHYSICS

Paper 9702/43

A2 Structured Questions

Key messages

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PHYSICS

Paper 9702/51
Planning, Analysis and Evaluation

Key messages

- To be successful in **Question 1**, candidates must ensure that their answers are detailed and include explanations.
- When determining information from the graph in **Question 2**, the labels on the axes should be checked so that the gradient is determined without power of ten errors.
- To gain credit in the numerical answers towards the end of **Question 2**, it is important that candidates show all their working.

General comments

Question 2 was generally answered better than **Question 1**. For **Question 2**, it was good to see that some Centres have spent time on the analysis section enabling their candidates to access the credit available. For **Question 1**, candidates should include greater detail in their answers, while for **Question 2** careless mistakes were often made in the plotting of points on the graph and there were a number of power of ten errors. **Question 1** has a number of boxes at the end of the question for the Examiner's use; they do also give a useful hint to candidates about the criteria used for awarding credit.

It is clear that the more able 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, CIE have produced two booklets – Teaching AS Physics Practical Skills and Teaching A2 Physics Practical Skills which are available from the Publications Catalogue or Teacher Support Website.

Comment on specific questions

Question 1

Candidates were required to design a laboratory experiment to determine the absorption coefficient of glass by varying the number of identical glass slides placed between a light source and a photocell and measuring the resulting e.m.f. produced across the photocell.

Credit was available for correctly identifying the independent and dependent variables, which was generally well answered. Further credit was then available for stating that the distance between the light source and the photocell and the intensity of the light remained constant.

Candidates received credit for the methods of data collection. Candidates are expected to draw a labelled diagram; the minimum features of the labelled diagram would include the light source, glass sheet(s), and photocell being in line. A voltmeter was expected to be drawn across the photocell. Common mistakes included the voltmeter shorted out, only one connecting wire drawn and power supplies connected across the photocell. Generally, only a minority of diagrams were conveying worthwhile information.

A correct method of measuring the thickness of a glass sheet received credit. A micrometer, not a vernier caliper, was required. A smaller proportion of candidates suggested taking many readings of the thickness of one sheet and averaging. Credit was often awarded for the use of a dark room.

Analysis of the data was awarded credit. It is expected that candidates would suggest the quantities that would be plotted on each axis of a graph; the majority of the candidates suggested plotting a graph of ln V against n or nt; other valid graphs such as log V against n or nt were credited. If the candidate explained

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how the absorption coefficient α could be determined from the gradient, where α was the subject of the equation, further credit was awarded. There was also additional detail credit available for stating the correct logarithmic equation.

Credit was available for the describing an appropriate safety precaution. Candidates should be encouraged to ensure that the safety precaution(s) are relevant to the experiment and are clearly reasoned; vague answers did not gain credit. Many candidates did not link the 'hazard' with a means of preventing it causing injury. Three hazards were considered; burns from the hot light source requires gloves/cool source, eye damage from the bright/intense light source requires dark glasses/do not look at source, cuts from the sharp ends of the glass sheet requires gloves. Just stating gloves or goggles did not score.

Candidates should be encouraged to write their plans including appropriate detail in order to receive further credit; often the candidates' answers lacked sufficient detail. Vague responses did not score. In addition to the points discussed above, candidates were also credited for discussing a method of ensuring the intensity of light remains constant and giving detail on how it would be achieved.

A large number of candidates gained credit for stating that the glass sheets would be cleaned before use.

Other marking points rarely seen were further detail regarding the alignment of the apparatus and methods of gaining a large value of voltage.

Usually, able candidates who have followed a 'hands on' practical course during their studies gain credit for additional detail. It is essential that candidates give appropriate detail in their answers.

Question 2

In this data analysis question candidates were given data on how the height of a column of nitrogen gas trapped in a tube varied with the pressure of the gas.

Part **(a)** asked candidates to state the quantity that the gradient would represent if a graph of p against $1/h$ were plotted. This was generally well answered.

In **(b)** most candidates calculated and recorded values of $1/h$. Most candidates gave a correct form of the unit of $1/h$. A small number of candidates did not record their values to an appropriate number of significant figures and there were also some rounding errors. It is expected that the number of significant figures in calculated quantities should be the same as or one more than the number of significant figures in the raw data. The absolute uncertainties in $1/h$ were usually calculated correctly. The Examiners allow a number of different methods and do not penalise significant figures at this stage.

The graph plotting in **(c)(i)** and **(ii)** was generally good. Common mistakes included not plotting the last data point correctly (2.009 was plotted instead of the correct value of 2.09) — candidates should check suspect plots. Candidates should also be advised to ensure that the size of the plots is small; large 'blobs' were penalised. Most candidates attempted to draw the line of best fit.

A significant number of candidates drew vertical uncertainty bars instead of horizontal ones. Misreading the square size on the $1/h$ axis and recording bars outside of tolerance were other common mistakes.

The worst acceptable straight line should be either the steepest possible line or the shallowest possible line that passes through the error bars of all the data points used for the line of best fit. The majority of the candidates labelled clearly the lines on their graph; in future lines not indicated will be penalised.

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

In **(d),** the majority of responses carried forward their gradient value as instructed but often derived a value for N with an incorrect power of ten; this was normally due to candidates not realising that the y-axis of the graph was labelled p / 10^5 Pa and thus there was a 10^5 power of ten error. Substitution methods did not score. There was a mixed response in finding the uncertainty in N. To gain credit the working needs to be clearly shown. Several candidates did not show any working and thus could not gain credit.

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For **(e)(i),** candidates needed to find the height *h* at a particular pressure *p* and temperature *T*. Credit was awarded for the correct substitution in the given formula, the common mistake being *T* = 12 K instead of 278 K. Further credit was available as a 'quality mark' for the whole question and a significant number of answers were within the permitted range. It was expected that the value would be given to 2 or 3 significant figures.

For **(e)(ii)** candidates were required to determine the percentage uncertainty in the height. A large number of candidates did not realise that the percentage uncertainty in *h* depended upon the percentage uncertainty of both *N* and *T*. Error carried forward was allowed for *N* and *T* but credit could only be given when the working was clear and easy to understand.

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PHYSICS

Paper 9702/52

Planning, Analysis and Evaluation

Key messages

- To be successful in **Question 1**, candidates must ensure that their answers are detailed and include explanations.
- When determining information from the graph in **Question 2**, the labels on the axes should be checked so that the gradient is determined without power of ten errors.
- To gain credit in the numerical answers towards the end of **Question 2**, it is important that candidates show all their working.

General comments

Question 2 was generally answered better than **Question 1** and a large number of candidates scored very highly. It was evident that Centres had spent time on the analysis section enabling their candidates to access the credit available. For **Question 1**, candidates should include greater detail in their answers, while for **Question 2** careless mistakes were often made in the reading information from the graph. There were some power of ten errors and some candidates did not show their working when determining the absolute uncertainty in **(e)(i)**. **Question 1** had a number of boxes at the end of the question for the Examiner's use; they do also give a useful hint to candidates about the criteria used for awarding credit.

It is clear that the more able 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, CIE have produced two booklets – Teaching AS Physics Practical Skills and Teaching A2 Physics Practical Skills which are available from the Publications Catalogue or Teacher Support Website.

Comments on specific questions

Question 1

Candidates were required to design a laboratory experiment to investigate how the horizontal displacement of a small ball is related to the vertical displacement from which it is projected. In addition, candidates were required to explain how the initial velocity of the ball could be determined from the results.

Credit was available for correctly identifying the independent and dependent variables. This was generally well answered, although a significant number of candidates designed an experiment in which the horizontal velocity of the ball was the independent variable. Further credit was awarded for stating that the horizontal velocity of the ball should be constant; the word 'controlled' is not acceptable and was not credited.

Credit was available for the methods of data collection. Candidates are expected to draw a labelled diagram; credit was not given for copying Fig. 1.1. It was expected that the diagram would indicate clearly how the vertical displacement p would be varied. Credit was awarded for the measurement of p and q using a metre rule but not for the use of a scale. A number of candidates stated that the experiment should be repeated. For the award of additional detail credit, candidates had to state clearly that they would repeat the measurement of q for each value of p and find the average. Vague answers such as "I will repeat the experiment many times" did not gain credit.

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The experiment required candidates to devise a method to accurately determine the position of the ball on the lower surface. Most candidates suggested various methods including the use of sand, dye and video recording the experiment. There was additional detail credit available for specifying that the video recording would record both the position and the rule and it would be played back in slow motion or frame by frame.

Credit was awarded for explaining how the initial horizontal velocity of the ball was kept constant. The Examiners were expecting candidates to describe how they would give the ball a constant impulse. A number of candidates discussed releasing the ball from a raised track; to gain credit, candidates had to state that the ball would be released from the same height on the track. There was credit for additional detail of using a curved track so as to ensure that the velocity was horizontal. A large number of candidates suggested the use of a spring loaded system; again, it was necessary for candidates to state that the spring was compressed to the same position each time. Candidates must be encouraged to include the necessary detail.

Credit was available for suggesting an appropriate method to ensure that the surface was horizontal. More able candidates suggested the use of a spirit level or checking the height at different places.

Credit was available for the analysis of the data. It is expected that candidates would suggest the quantities that would be plotted on each axis of a graph; the majority of the candidates suggested plotting a graph of q^2 against p. Other valid graphs such as q against $\sqrt{p}$, p against q^2 and $\sqrt{p}$ against q were also credited. The candidates needed to explain how the velocity v could be determined. It was expected that candidates would make v the subject of an equation using the gradient. Further credit was available for stating that the relationship between p and q was valid if the graph was a straight line passing through the origin. Some candidates suggested plotting various logarithmic equations such as lg p against lg q which gained credit. In this instance for further credit candidates then had to determine v in terms of the y-intercept. Credit for additional detail was awarded if the candidate stated that the relationship between p and q was valid if the graph was a straight line with the correct gradient. Often candidates just stated that the line would pass through the origin which is not necessarily true for logarithmic relationships.

Credit was available for describing an appropriate safety precaution. Candidates should be encouraged to ensure that the safety precaution(s) are relevant to the experiment and are clearly reasoned; vague answers did not gain credit. Creditworthy responses included precautions linked to preventing the ball rolling on the floor.

Candidates should be encouraged to write their plans including appropriate detail which can be awarded further credit; too often the candidates' answers lacked sufficient detail. Vague responses did not score. Credit was also given for a method to ensure that the ball left the table at right angles, additional detail on measuring q by finding the exact location of the landing position, and additional detail for determining the zero position, e.g. the use of a plumb line from where the ball leaves the upper surface.

To score highly on this question candidates should have followed a 'hands on' practical course so as to gain the necessary experience required to include the appropriate detail.

Question 2

In this data analysis question candidates were given data on how the reading V on a voltmeter varied with resistance R in a non-inverting operational amplifier circuit.

Part **(a)** asked candidates to state the quantity that the gradient would represent if a graph of V/E against $1/R$ were plotted. This was generally well answered, although weaker candidates often incorrectly included E in their answers. This first part is important since it should help candidates in many later parts.

In **(b)** most candidates correctly recorded the values required to an appropriate number of significant figures. A number of candidates were penalised for rounding errors. It is expected that the number of significant figures in calculated quantities should be the same as or one more than the number of significant figures in the raw data. The absolute uncertainties in V/E were usually calculated correctly, although there was a common error of ±0.5 in the first row – this was probably caused by candidates incorrectly dividing the maximum V by the maximum E. The Examiners allow a number of different methods and do not penalise significant figures at this stage.

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The graph plotting in **(c)(i)** and **(ii)** was generally good. Common mistakes included not plotting the points correctly — candidates should check suspect plots. A number of candidates did not plot 1/*R* correctly for the value 4.55; it is expected that the accuracy should be less than half a small square, thus 4.50 and 4.60 would not receive credit. Candidates should also be advised to ensure that the size of the plots is small; large 'blobs' were penalised. It was pleasing to see that most candidates attempted to draw the line of best fit. The worst acceptable straight line should be either the steepest possible line or the shallowest possible line that passes through the error bars of all the data points used for the line of best fit. The majority of the candidates labelled clearly the lines on their graph; in future lines not indicated may be penalised.

Part **(c)(iii)** was generally answered well, although candidates could often make their working clearer. Some candidates did not use a sensibly sized triangle for their gradient calculation. To determine the absolute error in the gradient, candidates were expected to find the difference between the gradient of the line of best fit and the gradient of the worst acceptable line. A large number of good candidates clearly indicated the points that they used from the line of best fit. Some candidates used their points from the table but did not gain credit because they did not lie on the line of best fit.

In **(d)** the value of *F* should have equalled the gradient value with an appropriate unit. Candidates often did not gain credit here either because the unit was omitted or because there was a power of ten error since the *x*-axis of the graph was labelled as $1/R\ /\ 10^{-3}\ \Omega^{-1}$ and the 10^{-3} factor had been omitted from their calculation. Most candidates gained credit for the uncertainty in *F*, which should have been the same as the uncertainty in the gradient.

For **(e)(i)** most candidates gained a value for *V*/*E*; the common error was forgetting to add 1 to *F*/*R*. The uncertainty in *V*/*E* caused many problems. Technically the absolute uncertainty in *F*/*R* should have been determined, although the Examiners on this occasion allowed percentage uncertainty calculations using *V*/*E*. The mark scheme contains a number of valid methods. The common error was to use maximum *F* divided by maximum *R*. Other errors included determining the absolute uncertainty in *R* as 5 Ω instead of 6 Ω. It cannot be stressed too strongly that candidates must show clearly their method of working to gain credit. In **(e)(ii)** candidates were required to determine the voltmeter reading. This part was used as a 'quality mark' for the whole question and it was pleasing to see many answers were within the permitted range; answers also had to be given to an appropriate number of significant figures.

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PHYSICS

Paper 9702/53

Planning, Analysis and Evaluation

Key messages

- To be successful in **Question 1**, candidates must ensure that their answers are detailed and include explanations.
- When determining information from the graph in **Question 2**, the labels on the axes should be checked so that the gradient is determined without power of ten errors.
- To gain credit in the numerical answers towards the end of **Question 2**, it is important that candidates show all their working.

General comments

Question 2 was generally answered better than **Question 1** and a large number of candidates scored very highly. It was evident that Centres had spent time on the analysis section enabling their candidates to access the credit available. For **Question 1**, candidates should include greater detail in their answers, while for **Question 2** careless mistakes were often made in the reading information from the graph. There were some power of ten errors and some candidates did not show their working when determining the absolute uncertainty in **(e)(i)**. **Question 1** had a number of boxes at the end of the question for the Examiner's use; they do also give a useful hint to candidates about the criteria used for awarding credit.

It is clear that the more able 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, CIE have produced two booklets – Teaching AS Physics Practical Skills and Teaching A2 Physics Practical Skills which are available from the Publications Catalogue or Teacher Support Website.

Comments on specific questions

Question 1

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