PHYSICS

Paper 9702/11
Multiple Choice

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

General comments

Candidates should be advised never to spend a disproportionately long time on any one question. They should also be advised to use the spaces on the question paper for their working. Care with units is essential. Prefix errors are a cause of many wrong answers as are corresponding power-of-ten errors. Some candidates would benefit from taking a moment to think whether a numerical answer has a sensible order of magnitude and to check that it makes basic sense.

Questions 4, **5**, **9** and **22** were found to be easy. **Questions 17**, **29** and **37** were difficult.

Comments on specific questions

Question 3

Candidates needed to take care throughout their working, and there were several mistakes possible in the working. Determining the area from the diameter, remembering to include *g* and also taking into account the two cables caused problems for many candidates.

Question 7

This was another question where extra care was necessary. The word 'horizontal' is important. The time of fall is given by $t = \sqrt{\frac{2h}{g}}$ and so the horizontal displacement is $r = u\sqrt{\frac{2h}{g}}$ for constant horizontal velocity u. The graph with the correct shape is **A**.

Question 10

This question required careful work with the signs of the speeds. For an elastic collision, the relative speed of approach must equal the relative speed of separation. The relative speed of approach is $u_1 + u_2$. The relative speed of separation is $v_2 - v_1$ because the spheres are shown travelling in the same direction after collision.

Question 17

Candidates needed to know that power P, resistive force F and velocity v are related by $P = Fv$. Only **D** satisfies this relationship.

Question 20

Answer **B** was relatively popular. This arrangement has twice the spring constant of a single spring, which can be deduced by considering the force on each spring when it is extended by the same amount as a single spring. Similarly **A** has half the spring constant of a single spring. Combining these two ideas leads to the conclusion that **C** must have the same spring constant as a single spring.

Question 26

Many candidates chose **A**. They had carried out the calculation correctly and determined that $\lambda / d = 0.135$ but they had not considered that there are intensity maxima either side of the central maximum. There are 7 maxima on each side (giving 14) and one central maximum, making a total of 15, which is **D**.

Question 28

The force on a particle of charge q in a uniform electric field of field strength E is given by $F = qE$. The acceleration is then given by $a = qE / m$ for mass m. Therefore the acceleration of the particle is constant and non-zero. Some candidates chose **D** but it is the acceleration, not the velocity, that is constant.

Question 29

The electric field lines must always be at right angles to a conducting surface, and candidates will be familiar with this idea from their study of the electric field between parallel plates. Candidates would benefit from further practice of drawing and interpreting electric field patterns in less familiar situations.

Question 37

The reading V on the voltmeter is given by $V = IR$ and this will only be proportional to the current I if the potential difference is measured across a fixed resistance R, which is the arrangement shown in the correct answer **B**. In both **A** and **C**, R is not constant so the reading will not be proportional to current. In **D** the voltmeter only measures the e.m.f. of the supply.

PHYSICS

Paper 9702/12
Multiple Choice

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

General comments

Candidates should be advised never to spend a disproportionately long time on any one question. They should also be advised to use the spaces on the question paper for their working. Care with units is essential. Prefix errors are a cause of many wrong answers as are corresponding power-of-ten errors. Some candidates would benefit from taking a moment to think whether a numerical answer has a sensible order of magnitude and to check that it makes basic sense.

Candidates found **Questions 12**, **15**, **16** and **30** difficult. **Questions 1**, **14**, **29** and **38** were relatively straightforward.

Comments on specific questions

Question 7

Initially the acceleration is g, but the acceleration falls away towards zero when the ball is going fast enough for air resistance to be equal to its weight. This is shown by **A**. Weaker candidates often chose **C**, suggesting that they were thinking that the graph was velocity against time rather than acceleration against time.

Question 11

Some candidates chose **C**. These candidates were familiar with collisions in one dimension but this is a more difficult question on two-dimensional collisions, a new topic on the syllabus. The equation in the first column cannot be correct because it does not take into account the vector nature of momentum.

Question 12

Taking moments about X provides evidence that R must be very much larger than W. This being the case, the value of the force at X must be larger than W, and with a component in a direction away from the wall.

Another approach is to consider that the lines of action of the three forces must pass through the same point. Extending the W and R vectors shows that they meet at a point below the object and lower than X, so the correct force arrow at X must be **D**.

Question 15

Candidates found this question difficult. Atmospheric pressure is caused by the weight of air above the point, so the correct method is to calculate the pressure caused by the part of the atmosphere between sea level and 5000 m, and to subtract this from the pressure at sea level.

Candidates answering **B** or **C** had both calculated the pressure difference correctly using the average density; those choosing **C** gave the correct answer because they had subtracted the pressure difference from 100 000 Pa. The incorrect answer **A** was popular; candidates choosing **A** had calculated $0.74 \times 9.7 \times 5000$ but this is not the atmospheric pressure.

Question 16

The parachutist is falling at constant velocity, so the kinetic energy of the parachutist is constant and therefore **B** is the right answer. Some candidates chose **A**, but the kinetic energy of the air increases as the parachutist falls.

Question 25

After half a time period, the string will be in the position shown by the dashed line and the point P has moved through a distance of $2A$, so **C** is correct.

Question 28

When the intensity of light passing through one of the slits is increased, complete cancellation cannot occur at the dark fringes. The dark fringes must become brighter. There is no change to the fringe separation, because this depends only on the frequency of the light. Some candidates chose **D**; these candidates did not understand the formation of the fringes, or perhaps misread the question and thought that the intensity through both slits had increased.

Question 30

Candidates needed to take care with units in order to obtain the correct answer. In particular, they needed to convert a mass of 0.5 mg into a weight of $0.5 \times 10^{-6} \times 9.8$ N. Dividing this by the charge of 1.0×10^{-12} C gives the answer **C**.

PHYSICS

Paper 9702/13
Multiple Choice

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

General comments

Candidates should be advised never to spend a disproportionately long time on any one question. They should also be advised to use the spaces on the question paper for their working. Care with units is essential. Prefix errors are a cause of many wrong answers as are corresponding power-of-ten errors. Some candidates would benefit from taking a moment to think whether a numerical answer has a sensible order of magnitude and to check that it makes basic sense.

Questions 21, **27**, **33** and **37** were found to be difficult. **Questions 12**, **30** and **39** were relatively easy.

Comments on specific questions

Question 7

Most candidates correctly identified that the sin and cos functions were reversed in **C** and **D**. To obtain the correct answer **B**, candidates needed to realise that the acceleration is negative but the value of g is positive (as given on page 2 of the Question Paper). This makes the equation with the negative sign correct.

Question 17

The correct answer is obtained by considering that (initial kinetic energy) – (work done against air resistance) = (gain in potential energy). Answer **C** was popular but this is the initial kinetic energy. Some candidates chose **B**, which is the gain in potential energy.

Question 21

This question required careful work with powers of ten, particularly in converting mm^2 to m^2. Candidates should also be careful with percentages; the strain in this case is 0.0030.

Question 25

Using the equation given, the intensity at Q will be a quarter of the intensity at P. Wave intensity is proportional to the amplitude squared, so the amplitude at Q will be half the amplitude at P, giving answer **D**. Many candidates chose **B**.

Question 27

The usual equation $n\lambda = d \sin\theta$ can be written $n\lambda = \sin\theta / N$ where N is the number of lines per unit length. The gradient of the graph shown is therefore Nn. Many candidates chose **C**, because they had not correctly thought about the difference between d and N.

Question 33

Candidates needed to read all of the options carefully before coming to a conclusion. Weaker candidates often chose **B**, but this ratio is not dimensionally correct.

Question 34

Stronger candidates did not find this question challenging but weaker candidates often chose **C**. They had correctly identified the semiconductor diode, but confused the direction of curvature of the line for the filament lamp.

Question 37

Candidates found this question difficult. The p.d. across the 11 Ω resistor is $11 \times 0.50 = 5.5$ V so the p.d. across each internal resistance is 0.5 V. The current through each internal resistance is 0.25 A. The internal resistance is then given by $r = 0.5\,\text{V} / 0.25\,\text{A} = 2.0\,\Omega$. The most popular incorrect answer was **A**.

PHYSICS

Paper 9702/21
AS Level Structured Questions

Key messages

- Candidates are sometimes unable to gain full credit because their descriptions are not given with sufficient detail, and they would benefit from providing more detail. Often answers are made unclear through the omission of certain key words and inappropriate use of everyday language.
- It is important not to prematurely round values to two significant figures at intermediate stages within a calculation as this may lead to an incorrect final answer. Candidates should instead wait until they obtain a final answer before rounding to an appropriate number of significant figures.
- Candidates need to present clearly all of their working in extended mathematical questions. Well-presented calculations show all the discrete steps in a logical order. This will often enable marks to be gained for the working even when a mistake has been made with the final answer.
- Many questions at AS Level require candidates to perform unit conversions, for example from mm^2 to m^2 or from g to kg. Errors due to incorrect unit conversions can add up over a number of different question parts and make a significant difference to the final mark for the paper. Candidates should continually practise converting between units when performing calculations.

General comments

A wide range of marks were awarded on this paper. There were some question parts that were deliberately very challenging in order to discriminate between stronger candidates. Other question parts were very straightforward to ensure that weaker candidates had opportunities to score marks.

Many candidates found **Question 6** difficult. This may indicate that candidates would benefit from further practice questions when studying topic 19 (Current of electricity) and topic 20 (D.C. circuits).

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

Comments on specific questions

Question 1

(a) Although there were many accurate estimates, a significant number of candidates had little ‘feel’ for the masses and volumes of these everyday objects. Candidates were more successful in estimating the mass of the metre rule than in estimating the volume of the ball. Many simply guessed the volume of the ball, while more successful candidates usually attempted to calculate it from an estimate of the radius.

(b) Power-of-ten errors were common and caused by not calculating the volume in units of m^3 or not calculating the mass in units of kg. It was important not to prematurely round the value of the volume to two significant figures as this leads to an incorrect value of the density. Some of the candidates did not double the fractional uncertainty in the diameter.

In the final answer, the absolute uncertainty in the density should be given to one significant figure. This needs to be accompanied by the value of the density quoted to the same number of decimal places as the absolute uncertainty.

Question 2

(a) The vast majority of the candidates knew how to calculate the horizontal and vertical components of the ball's velocity. In a few cases the two components were reversed.

(b) The candidates were given the maximum height of the ball and asked to show that it was correct. In this type of question, the marks are awarded for explicitly showing each stage of the calculation as well as the final answer. A small number of candidates equated the ball's initial kinetic energy to its gravitational potential energy at maximum height, but the most common calculation was to use the appropriate equation of uniformly accelerated motion. When substituting the values of the vector quantities into this equation, it is important to remember that these must always be substituted with the correct signs.

(c) Successful candidates presented all the intermediate calculations in a logical order that was easy to follow. It was important not to round any intermediate values that were calculated as this can lead to an incorrect final answer. Many weaker candidates could only get as far as calculating the time taken for the ball to reach maximum height. A significant number of candidates confused the horizontal displacement of the ball with its actual displacement.

Question 3

(a) (i) This was a straightforward introductory part of the question that was very well answered. Occasionally the unit of the mass of the ball was not converted into kg which then caused a power-of-ten error in the final answer.

(ii) The correct explanation is that the resultant force on the ball is zero and so the normal contact force is equal and opposite to the weight. It should be noted that an explanation based on Newton's third law is incorrect because the weight and the normal contact force act on the same body. A widespread misconception was that the normal contact force was the 'reaction force' to the ball's weight.

(b) (i) Well-prepared candidates were able to recall Newton's second law of motion without difficulty. A significant minority of candidates did not appreciate that it is incorrect to state the law as "force is equal to mass multiplied by acceleration".

(ii) This question was reasonably well answered. The most common error was not taking into account the opposite directions of the initial and final velocities, leading to the subtraction of the speeds when they should have been added.

(iii) Only a small minority of candidates understood that the change in momentum of the floor is equal and opposite to the change in momentum of the ball. Most candidates did not realise that the floor forms part of the system and so they considered the momentum change of only the ball.

Question 4

(a) This question required simple recall of knowledge for well-prepared candidates. Answers needed to be precise. It is insufficient to refer to "the energy stored in an elastic body" without stating that this is due to the deformation of the body. Weaker candidates either tried to explain gravitational potential energy or simply gave an expression for calculating elastic potential energy.

(b) (i) It was generally understood that Hooke's law is obeyed when force is proportional to extension. The majority of candidates did not read the question carefully and so did not use data from the graph to show that the law was obeyed. There were several possible approaches, the most common being to calculate two values of F/x from the graph line which are the same. Weaker candidates incorrectly thought that the line being straight was sufficient evidence on its own for Hooke's law being obeyed.

(ii) 1. This question was very well answered, although a small minority of candidates did not remember to convert the units of extension from cm to m.

2. Candidates usually stated a correct general formula for the work done to extend a spring or stated that the work done could be determined by calculating an area under the graph. The majority of candidates were not able to calculate the correct area in this situation where the graph line doesn't start from the origin. Sometimes the work done to extend the spring to 20 cm or to 40 cm was calculated, rather than the work done to extend the spring from 20 cm to 40 cm.

(c) The majority of candidates did not state that when a spring has not exceeded the elastic limit, it will return to its original length when the force is removed. A common misconception was that the spring must have exceeded the elastic limit when the force is no longer proportional to the extension.

Question 5

(a) The majority of answers were correct. Some candidates needed to read the units on the time axis more carefully to appreciate that the period was 4.0 ms and not 4.0 s.

(b) Most candidates could recall that intensity is proportional to the square of amplitude, but only the stronger candidates were able to use this relationship to determine the amplitude of wave Z. A common error was to think that wave Z must have twice the amplitude of wave X because it has twice the intensity.

The majority of candidates drew a sketch that correctly showed a 90° phase difference between waves X and Z, although a small minority drew a line corresponding to a 180° phase difference. A few candidates sketched their graph in the blank working space at the bottom of the page, despite being given a clear instruction to use Fig. 5.1. It was often impossible to award credit for these graphs because they were imprecise.

(c) (i) Many of the stronger candidates were awarded full credit. Other candidates sometimes calculated x / D for a single point on the graph line, rather than following the instruction to use the gradient of the line in their calculation. Power-of-ten errors were common owing to the incorrect conversion of units. The weakest candidates sometimes thought that the wavelength was equal to the gradient of the graph.

(ii) Many candidates did not read the question carefully and so did not refer to the effects on the graph. Those that did refer to the effects on the graph often incorrectly deduced that the gradient would become steeper rather than shallower. Only a small minority realised that the new graph line would have a smaller intercept on the *y*-axis and would be shifted completely below the original line.

Question 6

(a) Although this answer required only straightforward recall of knowledge, many candidates were unable to define the coulomb. Weaker candidates often wrongly stated that it was the product of current and time or could only mention that it was the unit of charge.

(b) The derivation of this expression is a new learning outcome in the syllabus content. Only the stronger candidates appear to have learnt this derivation and a significant number of weaker candidates made no attempt at an answer. Candidates who have learnt the algebraic derivation without fully understanding it sometimes became confused about whether the symbol v represented the average drift speed, the volume of the wire or the voltage across the wire. Another common error was to confuse the total charge in the wire with the charge of a single charge carrier.

(c) (i) It was expected that candidates would use the formula for average drift speed given to them in **(b)**. A significant number of candidates either ignored that formula or else inappropriately incorporated the lengths of the resistor wires into their ratio expression. Some candidates were able to set up a correct initial expression but then made errors in their subsequent algebraic manipulation of the fractions.

(ii) In 'show that' questions it is essential that candidates present their working as a series of logical steps that are clear to the Examiner. The majority of the candidates knew the formula that relates resistance to resistivity. However, many candidates found it difficult to manipulate a symbol expression in which one fraction is divided by another fraction.

(iii) Although there were many correct answers, a significant number of candidates did not attempt this question, perhaps because they didn't realise that they could do so without first answering parts

(c)(i) and **(c)(ii)**. The most common error was to calculate the potential difference across resistor Z instead of across resistor Y.

(iv) There were three different ways to calculate the ratio depending upon which formula for power was used. A significant number of candidates did not attempt this question, perhaps not realising that they could do so without needing to answer the previous question parts.

Question 7

Question 7 assessed new learning outcomes in the syllabus content. The majority of candidates had learnt this new area of knowledge.

(a) In this question, a small minority appeared to confuse neutrons with neutrinos.

(b) (i) In the vast majority of cases, a correct answer was given.

(ii) Generally a correct answer was given. A small minority of candidates reversed the quark structure of a proton and a neutron.

(c) (i) Most answers correctly referred to a proton and an electron. Only a minority correctly referred to an antineutrino, and common incorrect alternatives were neutrino and energy. Candidates should always be encouraged to read the question carefully. Although candidates were told that a word equation was required, some stated a symbol equation.

(ii) A significant number of candidates who had answered **(b)(i)** and **(b)(ii)** correctly were then unable to apply their knowledge of quark structure to this question.

PHYSICS

Paper 9702/22
AS Level Structured Questions

Key messages

- Candidates are sometimes unable to gain full credit because their descriptions are not given with sufficient detail, and they would benefit from providing more detail. Often answers are made unclear through the omission of certain key words and inappropriate use of everyday language.
- It is important not to prematurely round values to two significant figures at intermediate stages within a calculation as this may lead to an incorrect final answer. Candidates should instead wait until they obtain a final answer before rounding to an appropriate number of significant figures.
- Candidates need to present clearly all of their working in extended mathematical questions. Well-presented calculations show all the discrete steps in a logical order. This will often enable marks to be gained for the working even when a mistake has been made with the final answer.
- Many questions at AS Level require candidates to perform unit conversions, for example from mm^2 to m^2 or from g to kg. Errors due to incorrect unit conversions can add up over a number of different question parts and make a significant difference to the final mark for the paper. Candidates should continually practise converting between units when performing calculations.

General comments

The questions that required answers using basic theory were generally answered well. The descriptions for these questions were accurate and the calculations were generally well presented. The calculations in questions that needed some application of the theory were generally less well presented, in particular **Question 3** on the Young modulus and **Question 6** on the determination of the electric field strength. The lack of good presentation often led the candidates to make mistakes. The questions requiring a description and an application of knowledge would have benefited from better explanations, particularly **Question 4** on basic wave theory and **Question 5** on diffraction and interference with a diffraction grating.

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

Comments on specific questions

Question 1

(a) This was generally well answered. A small number of candidates used speed instead of velocity. A significant number of candidates defined acceleration as “rate of change of velocity per unit time”, which is the rate of a rate and not acceptable.

(b) (i) This was well answered by the vast majority of candidates. There were some answers that were rounded incorrectly from 1.89 to 1.8 or 1.90.

(ii) There were very good answers from the great majority of the candidates using one of the three methods available.

(iii) 1. The majority of candidates gave good answers to this question. There were some answers that started with the change in kinetic energy equal to $½(v – u)^2$. This is incorrect physics and could not be awarded credit. A small minority did not square the velocity term in their final calculation.

2. The majority of candidates obtained the correct answer. A common mistake was to use the distance down the slope rather than the vertical distance. A small minority used cos 40° instead of sin 40° when calculating the height. The incorrect use of g = 10 was seldom seen in this calculation.

(iv) Candidates found this part more challenging. A significant number obtained the correct answer. A common error was to disregard the instruction to use the answers from **(iii)**. The method used by these candidates was usually to determine the resultant force from the acceleration. A significant number of candidates equated the difference in the two energies directly with the frictional force.

(v) There were only a small number of correct solutions. A large proportion of candidates calculated the resultant force instead of the frictional force. A significant number were confused by the direction of the forces and the acceleration and made errors with the signs for these quantities.

Question 2

(a) The majority of candidates were able to start with the definition of pressure. Many were then able to work their way through to the required expression, although many answers lacked explanations of the substitutions being made. A significant number were not awarded full credit as they introduced symbols that were not used in the question and were not defined by the candidate. A large number of candidates equated the force acting on the base of the cylinder with *ma* (mass × acceleration) instead of *mg* (the weight of the liquid). A significant minority tried to prove the expression by equating base units but this approach could not be given credit.

(b) (i) The majority gave a correct response. Common mistakes were to suggest the pressure recorded when there was no liquid in the cylinder was either due to the weight of the cylinder or due to a systematic error.

(ii) Candidates found this question difficult. The majority of candidates used a one-point solution from the graph rather than determining the gradient. The power of ten given on the pressure axis was also omitted by a significant number. The density was often equated to the gradient omitting the factor of g.

Question 3

(a) This was well answered by most candidates.

(b) (i) A significant number of candidates ignored the command in the question to use the definition of the Young modulus. There were many correct solutions for the ratio. The presentation of these solutions was often very difficult to follow. Many expressions had no subject but just an equals sign followed by a numerical ratio. The inverse ratio was often given and the lack of clear presentation was considered the main reason for this error. Candidates should be reminded not to give final answers as fractions.

(ii) A small majority gave the correct response. Credit was not awarded to candidates who did not show wires that obey Hooke's law when extended by a force. A significant number labelled the lines the wrong way round even though they had the correct ratio in **(b)(i)**.

Question 4

(a) A significant number of candidates did not gain credit as they did not follow the instruction in the stem to refer to the direction of the propagation of energy. The answers given were generally imprecise with many referring to the direction of the wave travel or the direction of the motion of the wave. These answers were not considered to be precise enough to gain credit.

(b) The majority of candidates made a very good attempt using base units to show this relationship. There were some candidates who obtained the correct expression for one side only to find that this did not agree with their answer to the opposite side. Often they then attempted to change the wrong side of the equation and this resulted in an incorrect solution.

(c) (i) A significant number of candidates gave the correct response. A common mistake was to describe the change in frequency as a change in the frequency from the source rather than a change in the observed frequency. Another error was to refer to the observed frequency change as due to a change in position of the source rather than the relative motion between the source and the observer.

(ii) A significant number of candidates gave the correct response. There were many answers that were not awarded credit as they referred only to a reduction in intensity.

(d) The majority of candidates determined the correct answer. Some candidates confused the observed and source frequencies and a few confused the speed of the source and the speed of sound. The choice of signs in the given formula caused a problem for some candidates.

Question 5

(a) The descriptions of diffraction at a diffraction grating generally lacked detail. Mention of the wave passing through a slit, narrow gap or grating element was often omitted. The majority of candidates were able to explain the part played by interference. Very few candidates explained that the path difference between waves that arrive to form the first order maximum is λ.

(b) The majority of candidates obtained at least partial credit for the general formula. A significant number used the angle between the two second order maxima as θ, or calculated *d* rather than *N*. A number of candidates made errors involving powers of ten.

Question 6

(a) There were a significant number of correct answers. Most had the direction shown correctly. The majority of answers that were not given credit had lines drawn without the use of a ruler, lines that were clearly not equally spaced, lines that sloped or lines that did not extend from one plate to the other.

(b) This calculation provided a challenge to all candidates. A small minority obtained correct answers. The formula for electric field strength was often quoted correctly but a considerable number of candidates then substituted an energy or a velocity for *V*. The energy was often left in eV and not converted into J. The charge on the α-particle was often given incorrectly.

Question 7

(a) A very small number of candidates explained this correctly.

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

(ii) A significant number of candidates obtained the correct answer. Some candidates gave the potential difference across the internal resistance (the ‘lost volts’ in the battery) as the potential difference across the battery.

(c) (i) There seemed to be a large number of candidates who were unaware that the required equation was available on the formula page. The common error made by candidates using the correct equation was in the power of ten conversion required for the area.

(ii) This part was found to be very challenging for all candidates. There were some completely correct answers. A large proportion of the answers did not receive credit as they were imprecise. The diameter is quoted as changing to half the original value. A complete answer requires a quantitative response and therefore answers that describe the resistance as increasing without describing the actual factor in the change lacked the necessary detail. Many candidates thought the current would remain constant even though the resistance in the circuit had changed.

Question 8

(a) This was generally well answered. There were many spellings of *lepton* and *hadron*. A significant number showed a lack of knowledge of this learning outcome.

(b) (i) There were many answers that gave the correct symbols. The neutrino symbol caused the major problem for candidates and often was written in a form very similar to that for γ.

(ii) There were a significant number of correct answers.

(iii) There were very few correct answers.

PHYSICS

Paper 9702/23
AS Level Structured Questions

Key messages

- Candidates are sometimes unable to gain full credit because their descriptions are not given with sufficient detail, and they would benefit from providing more detail. Often answers are made unclear through the omission of certain key words and inappropriate use of everyday language.
- It is important not to prematurely round values to two significant figures at intermediate stages within a calculation as this may lead to an incorrect final answer. Candidates should instead wait until they obtain a final answer before rounding to an appropriate number of significant figures.
- Candidates need to present clearly all of their working in extended mathematical questions. Well-presented calculations show all the discrete steps in a logical order. This will often enable marks to be gained for the working even when a mistake has been made with the final answer.
- Many questions at AS Level require candidates to perform unit conversions, for example from mm^2 to m^2 or from g to kg. Errors due to incorrect unit conversions can add up over a number of different question parts and make a significant difference to the final mark for the paper. Candidates should continually practise converting between units when performing calculations.

General comments

The questions that required answers using basic theory were generally answered well. The descriptions for these questions were accurate and the calculations were generally well presented. The calculations in questions that needed some application of the theory were generally less well presented, in particular **Question 5** on conservation of momentum and **Question 6** on the determination of ratios of resistance and of drift speed. The lack of good presentation often led the candidates to make mistakes. The questions requiring a description and an application of knowledge would have benefited from better explanations.

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

Comments on specific questions

Question 1

(a) The majority of candidates indicated the correct scalars or vectors. There were some errors made in showing the correct classification for power and weight.

(b) (i) This question was generally well answered. Some candidates lost credit because they did not show arrows on the diagram to show the vector direction, or did not label the resultant with an arrow and a letter R as required.

(ii) 1. Some candidates calculated the average speed for each part of the journey and then determined the average of these two values. This method could not be given credit as it is not using total distance divided by total time.

2. The majority of candidates obtained the resultant displacement by a scale diagram or calculation from the right-angled triangle and went on to complete the determination of the average velocity. A significant number of candidates did not understand the difference between the average speed and the average velocity.

Question 2

(a) The descriptions of the effects on the reading for the diameter were generally lacking in detail. Answers generally discussed how these errors occur rather than describing the effect on the reading for the diameter.

(b) The explanation of accuracy was generally given correctly. The description for precision was often given in general terms and was not related to the diameter of the wire or the measuring instrument.

Question 3

(a) The explanation of kinetic energy was generally correct. There were some descriptions that did not refer to a body or a mass having this energy due to its motion. The gravitational potential energy was generally not well described. The descriptions omitted mention of the position of a mass in a gravitational field.

(b) (i) There were a significant number of good answers. Those candidates who used the average velocity to determine the displacement generally obtained the correct answer. The candidates who tried to determine the displacement from the area under the line did not always calculate the full area. They tended to calculate only the area under the triangle or the area shown on the graph.

(ii) This question was generally well answered. A small number of candidates chose points on the graph that were difficult to read accurately or used a one-point solution.

(iii) The majority of candidates completed this calculation correctly. There were some candidates who incorrectly used $\frac{1}{2}m(v - u)^2$ for the change in kinetic energy. A small number used incorrect values from the graph or did not square the velocity terms.

(c) The majority of candidates started correctly with work done equated to the change in potential energy. Only a small number went on to complete the question successfully. Some candidates changed previously correct answers for the change in kinetic energy in order for its value to equal that obtained for the work done.

Question 4

(a) There were very few candidates who included all three forces to explain that the resultant force was zero. The upthrust or the supporting force from the wire were often omitted.

(b) A small number of candidates were able to equate the difference in the readings on the spring balance with the upthrust and hence the weight of liquid displaced. A few candidates used the pressure difference between the top and bottom of the cylinder to determine the density of the liquid. A significant number calculated the density of the cylinder instead of the density of the liquid.

Question 5

(a) The statement of this law was not given accurately by the majority of candidates.

(b) (i) The precise explanation of this term was not given by the majority of candidates. Candidates should be encouraged to state that the <u>total</u> kinetic energy is conserved.

(ii) This question was generally well answered by the vast majority of candidates.

(iii) The majority of candidates gave at least one correct expression. A number of candidates gave an equation linking the initial and final momentum in each direction, which was not required by the question. A small number of candidates resolved the components incorrectly or omitted the mass.

(iv) A significant number of candidates equated the initial and final momentum in each direction correctly. The majority of candidates were not able to formulate the required equations. Very few candidates were able to obtain a solution to their equations.

Question 6

(a) Many candidates were not able to define the ohm. Many gave the statement that it was the unit of resistance or described it as the ratio of potential difference and current.

(b) (i) The majority of candidates gave the relationship between resistance and resistivity. Very few candidates were able to show the correct ratio between the resistance of P and that of Q. A small number considered the resistance to be proportional to l/d^2 and used this to show the correct value of resistance for Q.

(ii) This question was generally well answered. The expression for power was well known. The current through each resistor or the total resistance of the circuit was generally calculated correctly.

(iii) The majority of candidates found it difficult to obtain the ratio, which required use of a new learning outcome. There were a significant number of blank responses for this question. Those candidates who could use the required equation for drift speed often made errors in the manipulation of the relevant equations owing to poor presentation.

Question 7

(a) (i) The majority of candidates did not describe the adjustments to be made to the apparatus. The answers were generally related to the quantities that had to be changed and not how they would be changed using the apparatus.

(ii) Many candidates did not refer to the different amplitudes along the string. The description of a node and antinode was given by a small number of candidates.

(b) (i) A small minority of candidates gave the correct phase difference. Many answers showed that there was very little understanding of this term. Candidates would benefit from further practice of questions involving phase difference.

(ii) This was generally well answered. There were some mis-readings of the amplitudes from the graph and some who gave the intensity proportional to the amplitude.

Question 8

(a) A large number of answers did not distinguish between the two particles but gave the general properties of each. Answers that compared the charge or mass were often not given with the required detail. Vague answers such as “they are both positively charged” and “one is heavier than the other” are not sufficient at this level.

(b) There were many answers that gave the correct equation in terms of the symbols. The neutrino symbol caused a major problem for candidates and it was often written in a form very similar to that for γ. The numerical values for the positron caused the most problems. There were a significant number of answers that showed that candidates were not familiar with this learning outcome.

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

(ii) The majority of candidates gave the correct answer.

PHYSICS

Paper 9702/31
Advanced Practical Skills 1

Key messages

- Some candidates record values for quantities such as time or length that are obviously incorrect. Candidates should take a few moments to reflect on what the values should roughly be, and it would then become clear that the measuring instrument had been misread. Teachers are encouraged to help their candidates to develop a ‘feel’ for the correct sizes of physical quantities by, for example, trying to estimate the mass of a book, the current in a small lamp, the width of a human hair or the period of oscillation of a simple pendulum before attempting to measure them accurately.

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

- To score highly on **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. General points such as “avoid parallax error” or “use more precise measuring instruments” will not usually gain credit without further detail. Candidates should be encouraged to write about four different problems and consequently four different solutions to address these problems, and should not try to state four solutions to the same problem.

General comments

Centres generally did not have any difficulties in providing the equipment required for use by the candidates. Some Centres did not provide containers for **Question 2** with a lid that matched the description in the Confidential Instructions. Any deviation between the requested equipment and that provided to the candidates should be written down in the Supervisor’s Report, and this report must be sent with the scripts to Cambridge so that the Examiners can take this into consideration when marking. No ‘extra’ equipment should be available to the candidates. In some cases this may disadvantage candidates.

Any help given to a candidate should be noted on the Supervisor’s Report. Supervisors are reminded that help should **not** be given with the recording of results, graphical work or analysis.

Candidates were generally able to manipulate and use the apparatus well, and there were many good scripts. Candidates did not seem to be short of time and both questions were attempted by almost all the candidates. They demonstrated good skills in the generation and handling of data but could improve by giving more thought to the analysis and evaluation of experiments.

Comments on specific questions

Question 1

In this question, candidates were asked to investigate the motion of a loaded wooden strip.

(a) (ii) Successful candidates correctly noted a length for *x* which was in range with a correct unit. Candidates should always check to see if there is a unit given on the answer line. When the unit is not given, the candidate needs to think carefully and insert the correct unit matching the figure they write down. A few candidates omitted the unit or forgot to match their measurement with their unit e.g. 375 m rather than 375 mm.

(c) Successful candidates correctly noted a value for the period *T* which was in range with the correct unit of seconds. Stronger candidates realised that, to find the period, several consecutive oscillations (e.g. 10) should be measured. These candidates calculated the time for one oscillation as (time for 10 oscillations)/10. Some candidates incorrectly wrote their total time on the answer line, or inadvertently found the frequency by inverting the equation.

(d) Most candidates collected five sets of values for *x* and *T* showing that as *x* increased *T* increased, without help from their Supervisor. The majority of candidates drew neat, well-constructed tables. A small number of candidates muddled time and frequency and this gave an incorrect trend in the data.

Before taking readings, successful candidates benefited from considering the total variation that could be achieved with the apparatus and made changes to length *x* accordingly. Here, the stronger candidates varied *x* by 30 cm or more. Some candidates chose to vary the length by only a few centimetres and this could not gain credit.

Most candidates gave the correct quantity and unit in every column heading, with a separating mark, such as a solidus, between the quantity and unit. The majority of candidates were comfortable giving *x* / cm but some omitted the unit or gave an incorrect unit for T^2. A common mistake was to write $T^2(\text{s})^2$. The column heading should be written as T^2 / s^2 or $T^2\,(\text{s}^2)$.

The metre rule provided had millimetre markings and successful candidates used mm when recording their values of *x* e.g. 0.310 m or 31.0 cm. Values recorded to the nearest centimetre did not gain credit. Some candidates decided to increase or decrease the precision, for example by adding trailing zeros to give a greater precision than 1 mm e.g. 0.0650 m. Some candidates appear to do this to give all their measurements to the same number of significant figures, and this should be discouraged.

Many candidates recorded their calculated values for T^2 to an appropriate number of significant figures from their raw data, i.e. the same number of significant figures as (or one more than) the number in their raw time value(s).

Most candidates were able to calculate T^2 correctly. Many of the errors in the calculations were due to the incorrect rounding of the final value. When considering significant figures the source data is the column(s) containing the raw (initial) time readings.

(e) (i) Candidates were asked to plot a graph of T^2 on the *y*-axis against *x* on the *x*-axis. Successful candidates checked that axes were labelled as T^2 and *x* rather than omitting the labels or writing units only.

Successful candidates gained credit for using axes with scales that were simple to use, producing points spread over more than half the grid. Considering the *x*-axis, a scale used by successful candidates had one large square (2 cm) to represent 10 cm so that each small square had a value of 1 cm. Some candidates drew awkward scales on the *x*-axis (e.g. 15 small squares to represent 10 cm). This often also led to the loss of credit for plotting or for incorrect read-offs for the gradient and intercept because the scale was difficult to use correctly.

Candidates gained credit for plotting all the tabulated readings accurately i.e. to within half a small square. Successful candidates had access to sharp pencils to draw fine points or small crosses. Any points that have a diameter larger than half a small square are not credited. For successful candidates all points were close to a straight line. When candidates find a point is a long way from their line and are going to circle the point as anomalous, they need to check the plotting and the calculation. If the point is still a long way from the line, it is a good idea to check the readings.

(ii) Stronger candidates produced a well-drawn straight line which was smooth and continuous, with no joins, double lines or 'hairy' lines. These lines were produced using a 30 cm ruler. Candidates need to understand how to draw a line so that all the points have a good balance along the whole line and to practise drawing this type of line. Candidates may find it helpful during practice work to draw a thin line on a piece of acetate sheet and spend some time angling the line to get an understanding of where the best line lies. Often a better line can be drawn by rotation of the original line.

Candidates should avoid just joining the first and last (or any two) points regardless of the distribution of the other points. Some lines were forced so that the intercept could be easily read off the *y*-axis or were forced through the corner of the grid.

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

Many candidates were able to correctly read off the *y*-intercept at $x = 0$ directly from the graph, or correctly substituted a read-off into $y = mx + c$ to determine the *y*-intercept. Others needed to check that the point chosen was actually on the line of best fit and not just a point from the table.

When taking the read-off to find the intercept, successful candidates checked that the *y*-value being read was actually along $x = 0$. Often the scale began at, for example $x = 10$ cm, and the candidate assumed that it was $x = 0$. When making the substitution, care needed to be taken that the *x*-value and *y*-value were put into the correct places in the equation. The correct equation for the intercept is $c = y - mx$ and some candidates tried to use $c = y / mx$.

(f) Successful candidates showed a clear understanding of how the values found for gradient and intercept in **(e)(iii)** related to constants *P* and *Q*. These candidates stated the values with no need for any recalculation.

Candidates need to understand that it is not necessary to do any new calculations or solve simultaneous equations. Reworking to gain values for *P* and *Q* indicates that the gradient and intercept have not been identified as *P* and *Q* and this is not awarded credit.

The successful candidates included correct consistent units. Candidates would benefit from practising how to work out the units for constants in an equation.

Question 2

In this question, candidates investigated the motion of a container on a wooden board.

(a) Most candidates successfully recorded a value of *w* in range and to the nearest millimetre e.g. 0.230 m. A value such as 0.23 m lost credit as this is not given to the nearest millimetre. Successful candidates noticed that the unit of m was given on the answer line. There were some values of 23 m which were not awarded credit.

Measuring the length of the piece of wood was a static observation. Candidates could take all the precautions they needed to produce an accurate measurement, e.g. resting the rule on the wood parallel to the edge, lining up their head with the scale on the metre rule (which was accurately calibrated to the nearest mm) and taking time to make the observation. Therefore this measurement of *w* was not regarded as a source of uncertainty.

(b) (ii) Successful candidates accurately measured θ to the nearest degree, with a unit of degree or °. Many candidates lost credit by giving raw angles to 0.1°. The protractor provided had a scale marked to the nearest degree so the angle should be given as whole degree e.g. 16°.

The board is static and the protractor can be slid along until its centre is touching the lower edge of the board. Candidates need to be instructed on how to use the protractor in this way so they do not think the space at the bottom of the protractor presents a problem. Candidates had time to position their head to make an accurate measurement of the angle.

(iii) Most candidates were familiar with the method for calculating percentage uncertainty, though very few made a realistic estimate of the absolute uncertainty in θ of 1° to 3°. Many candidates stated the uncertainty as 0.5° (half of one division) which did not gain credit. When repeat readings were noted, the absolute uncertainty could be calculated as half the range of the repeated values, though some candidates did not remember to halve the range. The half-range calculation needed to be shown so that it was clear how the estimate of absolute uncertainty has been produced.

(c) (iii) Successful candidates recorded repeated values of *y*, noting that the unit of metres was given.

(d) (i) Successful candidates calculated *D* correctly to more than one significant figure. Candidates should be encouraged not to give their answers to one significant figure. Some candidates were not awarded credit because they divided by *y* rather than *w*.

(ii) Stronger candidates correctly justified the number of significant figures they had given for their value of *D* by referring to the number of significant figures given in their measurements of *w* and *y*. Candidates needed to state *w* and *y* in their answer; "raw data" or the phrase "values in the calculation" cannot be awarded credit. A few candidates stated "3 s.f." without any reasoning.

(e) (ii) Successful candidates recorded second values for θ and *y*, and found that when θ was increased, the value of *y* also increased.

(f) (i) Many candidates were able to calculate *k* for the two sets of data, showing their working clearly. Most candidates were able to successfully rearrange the equation and calculate $k = D / \sin\theta$ correctly. A common error was to use $k = \sin\theta / D$. Successful candidates gave their answers to 2 or 3 s.f. It is not valid to round both answers to 1 s.f. and then state that they are identical.

(ii) Successful candidates had three steps in their argument. They first state a criterion to be used for testing the relationship. This could be a percentage uncertainty that they think is a sensible limit for this particular experiment, e.g. 5% or 20%, or could be the percentage uncertainty found in **(b)(iii)**. Next they calculate the percentage difference between their values of *k*. Finally, they compare the percentage difference between their *k* values to the percentage uncertainty chosen and decide whether the relationship is supported or not supported. If the percentage difference between the two *k* values is less than the stated criterion, these successful answers then say that the relationship is supported. If the value of the percentage difference is greater than the value of the percentage uncertainty stated as the criterion, then the relationship is not supported. The candidates should make an explicit statement, e.g. "the relationship is not supported".

Some candidates are confused in their understanding of "percentage difference" and "percentage uncertainty".

(g) The experiment in **Question 2** always has flaws and can be improved. Successful candidates thought about difficulties while performing the experiment.

Many candidates recognised that two sets of data were insufficient to draw a valid conclusion or confirm the relationship. Successful candidates gave the two parts of this statement, i.e. reference to two sets and the idea of a conclusion. Stating "two sets are not enough" did not gain credit. A common misconception is that two sets of data cannot produce an "accurate" result; this idea did not gain credit.

Successful candidates identified problems with setting up this experiment e.g. the unstable arrangement, having a single clamp to grip the board. Credit is awarded for a practical, detailed solution that improves the set up e.g. support the board on a wedge of wood under the whole edge.

The measurement of distance *y* was difficult because the container moved quickly and it was difficult to identify the exact point where it rolled off the board. Credit was not given when candidates suggested it was difficult to measure *y* without giving a reason why it was difficult. A suggestion of changing the board was not credited, but some stronger candidates gained credit by suggesting the addition of a scale to the board.

Credit is not given for suggestions that could be carried out in the original experiment, such as repeating measurements. Vague or generic answers such as 'too few readings', 'difficult to measure *y*' (without stating a reason), 'systematic error', 'parallax error', 'air conditioning', 'turn off air con', 'faulty apparatus', 'use a set square' or 'use an assistant' cannot be given credit.

The key to this section is for candidates to identify genuine problems associated with setting up this experiment and in obtaining readings. Candidates are encouraged to suggest detailed practical solutions that either improve technique or give more reliable data.

PHYSICS

Paper 9702/32
Advanced Practical Skills 2

Key messages

- Some candidates record values for quantities such as time or length that are obviously incorrect. Candidates should take a few moments to reflect on what the values should roughly be, and it would then become clear that the measuring instrument had been misread. Teachers are encouraged to help their candidates to develop a 'feel' for the correct sizes of physical quantities by, for example, trying to estimate the mass of a book, the current in a small lamp, the width of a human hair or the period of oscillation of a simple pendulum before attempting to measure them accurately.

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

- To score highly on **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. General points such as "avoid parallax error" or "use more precise measuring instruments" will not usually gain credit without further detail. Candidates should be encouraged to write about four different problems and consequently four different solutions to address these problems, and should not try to state four solutions to the same problem.

General comments

Centres generally did not have any difficulties in providing the equipment required for use by the candidates. Any deviation between the requested equipment and that provided to the candidates should be written down in the Supervisor's Report, and this report must be sent with the scripts to Cambridge so that the Examiners can take this into consideration when marking. No 'extra' equipment should be available to the candidates. In some cases this may disadvantage candidates.

Any help given to a candidate should be noted on the Supervisor's Report. Supervisors are reminded that help should **not** be given with the recording of results, graphical work or analysis.

The general standard of the work done by the candidates was good, with many excellent scripts. Most calculations were carried out accurately, including correct rounding of the final values. Candidates did not seem to be short of time and both questions were attempted by almost all the candidates.

Comments on specific questions

Question 1

In this question, candidates were asked to investigate the oscillations of a suspended cardboard shape.

(b) (i) Most candidates recorded a value for θ in the expected range, although in some cases it was given to the nearest 0.1°. This precision was not possible with the specified protractor.

(iv) Many candidates demonstrated good practice in timing the oscillations. When finding the time period T of oscillations it is more accurate to time a group of the oscillations, i.e. nT (where n is at least 5). This should be repeated before finding the average nT and then dividing by n to give T.

Weaker candidates were not familiar with the definition of period. Some gave the value of 10*T* in place of *T*, and a few recorded the time for the oscillations to die away completely.

(d) Presentation of tables was generally clear and neat. Most candidates recorded six sets of values of θ and *T* without any assistance from the Supervisor.

A few candidates gave one or more measurements greater than 90° for θ. These values were not possible for the specified apparatus.

Stronger candidates included a sufficiently wide range of θ values in their table. Including the initial data from **(b)** and **(c)** would have enabled many other candidates to obtain credit for using a suitable range.

Most candidates gave correct column headings, including units where appropriate. A few did not realise that tan θ has no unit and so $1/\sqrt{\tan\theta}$ also has no unit.

Examiners expected all measurements of time to be recorded to the nearest 0.01 s (or all to the nearest 0.1 s). In many cases only the final value of *T* was recorded in the table. If this was to a greater precision as a result of averaging and the measured values were not shown, the candidate could not be awarded credit for the correct precision of the measured values.

Based on values of θ with 2 significant figures, most candidates recorded their calculations for $1/\sqrt{\tan\theta}$ to a suitable number of significant figures (2 or 3).

Nearly all candidates calculated the values for $1/\sqrt{\tan\theta}$ correctly.

(e) (i) Most graphs were drawn to a good standard, with accurate and clear plotting of points.

Scales were usually simple, so it was easy to avoid mistakes when reading off coordinates. In some cases the points were compressed into too small an area of the grid.

In the majority of cases, the scatter of points about a straight line was small so the candidates could be awarded credit for the quality of their results.

(ii) Some candidates were able to draw acceptable lines of best fit. There should be a clear straight line with a balanced distribution of points either side along the entire length. Some lines needed rotation to get a better fit, or an anomalous point needed to be identified to justify the line drawn. Some lines lost credit for being joined in the middle where the candidate had used too short a ruler.

(iii) Most candidates knew how to find the gradient and intercept of their line, and carried out the procedure accurately. There were some cases of using too small a triangle to establish the gradient or of using values from the table rather than reading them from the graph. A few candidates made the error of reading the intercept from the *y*-axis when the *x*-axis did not start at zero (the intercept value had to be calculated if this was the case).

(f) Most candidates recognised that *p* was equal to the value of the gradient and *q* was equal to the intercept as calculated in **(e)(iii)**. Values calculated by other methods (e.g. from simultaneous equations) were not accepted as the question specifically asks for the answers in **(e)(iii)** to be used.

Many candidates included the correct units for their *p* and *q* values (which were seconds in both cases).

Question 2

In this question, candidates were required to investigate the force exerted by a stream of water.

(a) (i) Nearly all candidates recorded a value for *h* in the expected range, though in some cases the value was only recorded to the nearest cm.

(ii) Measuring the diameter of the bottle was not straightforward owing to curvature of the base, but most candidates gave a reasonable value for *d*. Again, some *d* values were only given to the nearest cm.

(b) Most candidates were familiar with the procedure for calculating percentage uncertainty, though many candidates used 1 mm as their estimate of the absolute uncertainty in *d*, and this was too small in view of the parallax difficulties.

(c) (i) Some candidates had difficulty interpreting their stopwatch display (e.g. recording 1 min 15.3 s as 115.3 s). If the candidate's value for *t* was outside the expected range it could still gain credit after comparison with the Supervisor's results, provided these had been submitted.

Some candidates blocked the hole with a finger while they added water only up to the top line on the bottle. This was not necessary and suggested that the candidates had not read the instructions carefully.

(ii) There were very few mistakes in the calculation of the flow rate *R*, although some candidates used the height of the bottle above the bench for *h* instead of the separation of the lines.

(d) (ii) Measurement of the height of the strip x_1 was difficult owing to constant movement when the stream of water was falling on it, but most candidates recorded a value to the nearest mm and included a unit.

(e) All candidates recorded additional results when they repeated the experiment using the second bottle. A few candidates confused their x_1 and x_2 values so that it appeared that the strip moved further down instead of up when the stream of water was removed.

Most candidates correctly found that the change $x_2–x_1$ increased when the flow rate was greater.

(f) (i) Most candidates were able to calculate *k* correctly for each of the two bottles, though in a few cases the final value was rounded to only 1 significant figure.

(ii) There were many good answers when considering the validity of the equation. Stronger candidates looked at the percentage difference between their two *k* values and then decided whether it was within a stated tolerance. General statements such as "this is valid because the values are close to each other" were not credited.

(g) Stronger candidates identified problems associated with carrying out this particular experiment and in obtaining readings, and gave sufficient detail of both the problem and of a method of overcoming it.

Many candidates recognised that two sets of data were insufficient to draw a valid conclusion, and suggested investigating additional flow rates before considering the variation in *k* values. The difficulty in measuring the bottle diameter due to parallax was often listed, as was the suggestion of using calipers. Movement of the strip was identified as a problem when measuring the strip height, and the idea of positioning a scale near the strip and then making a video recording was often described. The use of a video (this time with a timer in view) was also suggested to reduce the problem in judging when the level reached the lines on the bottle.

Credit was not given for suggestions that could be carried out in the original experiment, such as repeating measurements, or viewing a scale at eye level to avoid parallax error. Vague answers such as 'systematic error', 'parallax error' (on its own), 'use an assistant', or 'use water level sensors' were not given credit.

The key to this section is for candidates to identify genuine problems associated with setting up this experiment and in obtaining readings. Candidates are encouraged to suggest detailed practical solutions that either improve technique or give more reliable data.

PHYSICS

Paper 9702/33
Advanced Practical Skills 1

Key messages

- Some candidates record values for quantities such as time or length that are obviously incorrect. Candidates should take a few moments to reflect on what the values should roughly be, and it would then become clear that the measuring instrument had been misread. Teachers are encouraged to help their candidates to develop a 'feel' for the correct sizes of physical quantities by, for example, trying to estimate the mass of a book, the current in a small lamp, the width of a human hair or the period of oscillation of a simple pendulum before attempting to measure them accurately.

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

- To score highly on **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. General points such as "avoid parallax error" or "use more precise measuring instruments" will not usually gain credit without further detail. Candidates should be encouraged to write about four different problems and consequently four different solutions to address these problems, and should not try to state four solutions to the same problem.

General comments

Centres generally did not have any difficulties in providing the equipment required for use by the candidates. Some Centres provided different wires in **Question 2** to those stated on the Confidential Instructions. Some candidates and Centres mixed up the two wires. Any deviation between the requested equipment and that provided to the candidates should be written down in the Supervisor's Report, and this report must be sent with the scripts to Cambridge so that the Examiners can take this into consideration when marking. No 'extra' equipment should be available to the candidates. In some cases this may disadvantage candidates.

Any help given to a candidate should be noted on the Supervisor's Report. Supervisors are reminded that help should **not** be given with the recording of results, graphical work or analysis.

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

Comments on specific questions

Question 1

In this question, candidates were asked to investigate a wooden rod with several forces acting on it.

(b) (ii) The majority of candidates correctly stated a value of y in the appropriate range. A few candidates omitted the unit.

(iii) Many candidates correctly stated a value for the angle θ to the nearest degree and in the right range. Some candidates stated a value such as 43.0° indicating that they could read their angle to the nearest tenth or half a degree, but the smallest division is one degree. Other candidates stated a value of θ out of range because they had incorrectly set up the apparatus or misread the protractor.

(d) Many candidates were able to collect six sets of values of *m, y* and θ without any assistance from the Supervisor, and the results showed a correct trend. A few candidates stated a value for $m = 0$ which was not accepted.

Many candidates extended their range of *m* values to include $m < 150$ g and $m > 400$ g. A large number of candidates increased their values from $m = 100$ g in intervals of 50 g up to 350 g but this did not take full advantage of the masses made available to them.

Some candidates were awarded credit for using the correct column headings in their tables, giving both the quantity recorded and suitable units for each quantity, with the two separated by a solidus or with the units in brackets. Many candidates either omitted the units or the separating mark for $m \sin\theta$ or θ. Some candidates stated the wrong units for $m \sin\theta$ e.g. kg° instead of kg.

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

About half the candidates recorded their calculated values for $m \sin\theta$ to an appropriate number of significant figures. Many candidates either stated too many significant figures or gave the calculated value to one significant figure, especially if the value was very small.

Some candidates calculated values for $m \sin\theta$ correctly. Many candidates calculated this value incorrectly either by working out $y \sin\theta$ or calculating $\sin\theta$ using the radian (instead of degree) setting on the calculator. A few candidates rounded their answers incorrectly and could not gain credit.

(e) (i) The size and scale of the graph axes chosen was varied. It is expected that the points plotted occupy more than half the graph grid available and the scale is easy to read. A large number of candidates drew awkward scales on the *x*-axis (multiples of 3 and 30 were common and multiples of unusual numbers such as 23.5 were occasionally seen). This often also led to the loss of credit for plotting or for incorrect read-offs for the gradient and intercept because the scale was difficult to use correctly.

Many candidates gained credit for plotting their tabulated readings correctly. A few candidates labelled the axes $m \sin\theta$ when in fact the values were something different (e.g *m*). A few candidates plotted the wrong graph (e.g. *y* versus *m*). If a point seems anomalous, candidates should be encouraged to repeat the measurement to check that an error in recording has not been made. If such a point is ignored in assessing the line of best fit, the anomalous point should be labelled clearly, e.g. by circling the point.

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

(ii) Some candidates were able to draw carefully considered lines of best fit, but others joined the first and last points on the graph regardless of the distribution of the other points. There should always be a balanced distribution of points either side of the line along the entire length. Many lines needed rotation to get a better fit, or an anomalous point needed to be identified to justify the line drawn. Some candidates lost credit for lines that were kinked in the middle (candidates used too small a ruler), by drawing a double line (broken pencil tip) or by drawing freehand lines without the aid of a ruler.

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

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

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

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

Candidates found it difficult to record a value with consistent units in range for *P* (e.g. $\text{cm}\,\text{g}^{-1}$ or $\text{m}\,\text{kg}^{-1}$) and *Q* (e.g. m). Many candidates stated incorrect units by including the angle unit e.g. *P* ($\text{m}\ °\ \text{kg}^{-1}$) whilst others omitted units or used cm throughout the experiment but then stated m on the answer line without converting the powers of ten.

Question 2

In this question, candidates were required to investigate the movement of a loaded wire.

(a) (ii) Some candidates recorded a value for *d* in range to the nearest 0.01 mm (or 0.001 m). Some candidates made a power of ten error, recording that their wire was 37 mm or 38 cm in diameter. In some Centres, candidates stated incorrect readings from the micrometer (e.g. 0.38 mm was read off as 0.88 mm). These candidates would benefit from more practice in using micrometers.

(iii) Most candidates correctly calculated *A* with consistent units. Some candidates stated inconsistent units (i.e. used *d* in mm in the equation and stated m^2 for the area unit) or omitted the unit in the answer.

(b) (iii) Many candidates recorded values of *L* with a unit in range.

(iv) Most candidates were familiar with the equation for calculating percentage uncertainty, though a few candidates made too small an estimate of the absolute uncertainty in the value of *L*, typically 1 mm (the smallest reading). This was too small as it was awkward to place a ruler near to the wire because the clip was in the way. Some candidates repeated their readings and correctly gave the uncertainty in *L* as half the range, while other candidates did not halve the range.

(c) (i) Many candidates calculated *C* correctly.

(ii) Candidates found it difficult to justify the number of significant figures they had given for the value of *C*. Many candidates gave reference to just 'raw' readings without stating what the raw readings were, or related their significant figures to *L* and *A* without referring to *d*.

(d) (ii) Most candidates recorded a value for *T* to at least the nearest 0.1 s and in range. Others mis-read the stopwatch, e.g. giving 0.0083 s instead of 0.83 s. Some candidates worked out $1/T$. Some weaker candidates incorrectly stated their value for $5T$ or $10T$ on the answer line instead of *T* so that their answers were out of range.

(e) (ii) The majority of candidates recorded a second value of *d* and *L*.

Most candidates recorded a second value of *T*.

Most candidates recorded a value for *T* which was larger than for the thicker wire.

(f) (i) Many candidates were able to calculate *k* for the two sets of data, showing their working clearly. A common error was to incorrectly rearrange the equation to calculate *k* (using C/T instead of T/C).

(ii) Some candidates calculated the percentage difference between their two values of *k*, and then tested it against a specified percentage uncertainty, either taken from **(b)(iv)** or estimated themselves. Many candidates omitted any sort of criterion. General statements such as "this is valid because the values are close to each other" were not credited.

(g) Many candidates recognised that two sets of data were insufficient to draw a valid conclusion. Many candidates stated that the wire was bent or that it was difficult to judge the end of an oscillation. Another common valid problem was that the wire was difficult to measure as the clip and the hook were in the way of the ruler, giving rise to parallax error in the reading of *L*.

Common valid solutions were to take more readings and plot a graph, use a larger mass or use a video and view with a timer/frame-by-frame.

Credit is not given for suggestions that could be carried out in the original experiment, such as repeating measurements. Vague or generic answers such as ‘too few readings’, ‘difficult to measure *L*’ (without stating a reason), ‘systematic error’, ‘parallax error’ (on its own without stating what measurement would be affected), ‘air conditioning’, ‘turn off air con’, ‘faulty apparatus’, ‘use a set square’ or ‘use an assistant’ cannot be given credit. Many improvements could not be credited because they were not specific enough or relied heavily on automatic/robotic devices. Other devices could not gain credit unless there was detailed clarification. For example, if a fiducial marker is to be used then its position should be described. A video recording is only an improvement in this experiment if there is reference to some sort of timing device.

The key to this section is for candidates to identify genuine problems associated with setting up this experiment and in obtaining readings. Candidates are encouraged to suggest detailed practical solutions that either improve technique or give more reliable data.

PHYSICS

Paper 9702/34
Advanced Practical Skills 2

Key messages

- Some candidates record values for quantities such as time or length that are obviously incorrect. Candidates should take a few moments to reflect on what the values should roughly be, and it would then become clear that the measuring instrument had been misread. Teachers are encouraged to help their candidates to develop a 'feel' for the correct sizes of physical quantities by, for example, trying to estimate the mass of a book, the current in a small lamp, the width of a human hair or the period of oscillation of a simple pendulum before attempting to measure them accurately.

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

- To score highly on **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. General points such as "avoid parallax error" or "use more precise measuring instruments" will not usually gain credit without further detail. Candidates should be encouraged to write about four different problems and consequently four different solutions to address these problems, and should not try to state four solutions to the same problem.

General comments

A few Centres provided a d.c. supply voltage much less than the 10 V specified in the Confidential Instructions for **Question 1**. This meant that the range of values of V_C available to the candidates was limited. Examiners were able to make allowance for this when Centres had provided sample results but could not do so if the results were not provided.

Any help given to a candidate should be noted on the Supervisor's Report. Supervisors are reminded that help should **not** be given with the recording of results, graphical work or analysis.

In **Question 1**, candidates were asked to measure the time for a capacitor to charge to different voltages. This took several seconds, but some candidates recorded values of 0.01 s or less. In **Question 2**, candidates were asked to measure the diameter of a copper wire using calipers. Some candidates recorded answers as large as several centimetres, or as small as 0.01 mm. These errors could be reduced by careful thought about the order of magnitude of realistic answers.

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

Comments on specific questions

Question 1

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

(b) (ii) Most candidates calculated the value of $0.9V_S$ correctly, though some recorded their values to too few significant figures, particularly where the value for V_S was greater than 10.0 V. A few candidates seemed to misunderstand what was meant by $0.9V_S$.

(c) (ii) Most candidates were able to record a value for *t* in the range 1.0 s to 9.0 s (the theoretical value for the capacitor to charge to a voltage of 4.0 V is approximately 5 s). Some candidates misread the stopwatch, recording values for *t* less than 0.1 s, almost certainly confusing the minutes and seconds display on the stopwatch. For example, 0:05:25 on a stopwatch display was recorded as 0.0525 s.

(d) (ii) Almost all candidates recorded six values of V_C and *t* correctly, showing the correct trend (*t* should increase as V_C increases).

Most candidates included at least one value for V_C at, or below, 3.0 V but fewer candidates included at least one value equal to, or above, 8.0 V. In any experiment it is good practice to try to include both the smallest and largest values possible.

Most candidates were awarded credit for using the correct column headings in their tables, giving both the quantity recorded and suitable units for each quantity, with the two separated by a solidus, or with the units in brackets. A few candidates included a column for V_S but without recording a unit.

Most candidates recorded all their raw values of *t* to the nearest 0.1 s or all to the nearest 0.01 s. A few candidates needed to be more consistent in the precision of their values of *t*. Raw readings of a quantity should all be recorded to the same precision, and not necessarily to the same number of significant figures.

(e) (i) Candidates were required to plot a graph of V_C on the *y*-axis against *t* on the *x*-axis. Most gained credit for drawing appropriate axes, with labels and sensible scales. Others chose extremely awkward scales making the correct plotting of points much more difficult. This often also led to the loss of credit for plotting or for incorrect read-offs for the gradient and intercept because the scale was difficult to use correctly. A few candidates chose non-linear scales.

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

Most candidates plotted their points on the graph paper carefully. Others needed to draw the plotted points so that the diameters of the points were equal to, or less than, half a small square (a small pencil cross is recommended). Some candidates can improve by plotting the points more accurately, i.e. to within half a small square.

(ii) Some candidates were able to draw a smooth curved line which was a good fit to the points plotted, with a reasonable distribution of points above and below the line. Others attempted to join the points with a wavy or ‘zig-zag’ line. A few candidates drew very thick or ‘hairy’ lines.

(f) (ii) Some candidates drew a good tangent to the curve at $V_C = 0.5V_S$. Others drew a line which either cut the curved line at $0.5V_S$ or did not touch the curved line at all. A few candidates did not seem to understand what was meant by $0.5V_S$.

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

It is important that candidates show their working, making it clear which points they have chosen for the read-offs e.g. by drawing the triangle on the graph. A value for the gradient without any clear working showing how the value was obtained does not receive credit.

Some candidates used points on the curved line rather than the tangent, or taken directly from the table, to calculate the gradient, and could not be awarded credit.

Some candidates correctly read off the y-intercept at $t = 0$ directly from the graph. Others needed to check that the x-axis started with $t = 0$ (i.e. no false origin) for this method of finding the intercept to be valid.

Many candidates correctly substituted a read-off into $y = mx + c$ to determine the y-intercept. Others needed to check that the point chosen was actually on the tangent, and not a point from the curved line.

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

Most candidates recorded correct units for a (V s^{-1}) and b (V). Some omitted the units for a and b.

(h) Most candidates calculated the value of T correctly, using the equation given in the question and the values obtained earlier for V_S and a. Others used an incorrect value for V_S, usually the value for $0.9V_S$ calculated in **(b)(ii)**.

Many candidates obtained a suitable value for T in the range 8.0 s to 14.0 s but were not awarded full credit because they omitted the unit for T.

Question 2

In this question, candidates were asked to investigate the relationship between the dimensions of a spring and its spring constant.

(a) Most candidates recorded a value for d in the range 0.5 mm–0.9 mm successfully, giving their answers to the nearest 0.1 mm (or 0.01 mm if digital calipers were used).

(b) (iii) Most candidates were able to measure the value of x correctly, obtaining a value in the range 11 mm–19 mm, with a suitable unit, but fewer candidates repeated their measurement of the diameter.

(c) Most candidates were familiar with the equation for calculating percentage uncertainties but underestimated the absolute uncertainty in the value of x. Many candidates simply used the smallest division on the ruler (1 mm) as the basis for estimating the absolute uncertainty, not taking into account the variability of the diameter of the spring along its length. A good estimate of the absolute uncertainty in x would have been 2 mm–5 mm.

(e) (ii) Almost all candidates recorded a value for h_1 with a consistent unit, though a few candidates recorded their answer to too great a precision (to the nearest 0.1 mm rather than 1 mm).

(iv) Most candidates were able to calculate a value for k correctly, recording their value to an appropriate number of significant figures. As m is given to two significant figures and g to three significant figures, the value of k should normally be given to two or three significant figures. The exception would be if the difference $h_1 - h_2$ was to one significant figure (e.g. 17.9 – 17.2 = 0.7 cm), in which case k should be expressed to one or two significant figures.

(f) Almost all candidates were able to record second values for n and x, together with second values for h_1 and h_2. Most candidates obtained a smaller value for $h_1 - h_2$ for the spring with the smaller diameter (the stiffer spring).

(g) (i) The great majority of candidates were able to calculate c correctly for the two sets of data, showing their working clearly. A few candidates calculated k / D^3n, or recorded their final answers to only one significant figure.

(ii) Most candidates calculated the percentage difference between their two values of c, and then tested it against a specified percentage uncertainty, either taken from **(c)** or estimated themselves. Where candidates state a percentage uncertainty value themselves, it is a good idea to try to justify this value in some way, particularly if a very large percentage uncertainty is suggested.

Some candidates gave answers such as "the difference between the two *c* values is very large/quite small" which is insufficient for credit—a numerical percentage comparison is required here.

(h) Many candidates recognised that two sets of data were insufficient to draw a valid conclusion. Some candidates simply described measurements that were difficult to make without explaining why they were difficult e.g. "it was difficult to measure the diameter of the wire". Answers such as "*d* was difficult to measure because it is small" or "there is a large percentage uncertainty in measuring *d*" would have gained credit.

Valid improvements included taking more readings (for different diameters of spring) and then plotting a suitable graph to test the suggested relationship. Other good answers included:

- using a micrometer rather than calipers to measure the diameter of the wire
- recording the number of turns *n* to the nearest quarter-turn
- using larger masses so that the difference between h_1 and h_2 was larger (and the percentage uncertainty in the value smaller)
- suggesting a method of marking the wooden rods (e.g. grooves or lines) to ensure equally-spaced coils.

Some candidates suggested improvements which should have been carried out in the original experiment such as repeating measurements and calculating average values, or limiting parallax errors by reading the ruler 'square on'. No credit is given for these suggestions.

The key to this section is for candidates to identify genuine problems associated with setting up this experiment and in obtaining readings. Candidates are encouraged to suggest detailed practical solutions that either improve technique or give more reliable data.

PHYSICS

Paper 9702/35
Advanced Practical Skills 1

Key messages

- Some candidates record values for quantities such as time or length that are obviously incorrect. Candidates should take a few moments to reflect on what the values should roughly be, and it would then become clear that the measuring instrument had been misread. Teachers are encouraged to help their candidates to develop a 'feel' for the correct sizes of physical quantities by, for example, trying to estimate the mass of a book, the current in a small lamp, the width of a human hair or the period of oscillation of a simple pendulum before attempting to measure them accurately.

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

- To score highly on **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. General points such as "avoid parallax error" or "use more precise measuring instruments" will not usually gain credit without further detail. Candidates should be encouraged to write about four different problems and consequently four different solutions to address these problems, and should not try to state four solutions to the same problem.

General comments

Centres generally did not have any difficulties in providing the equipment required for use by the candidates. Any deviation between the requested equipment and that provided to the candidates should be written down in the Supervisor's Report, and this report must be sent with the scripts to Cambridge so that the Examiners can take this into consideration when marking. No 'extra' equipment should be available to the candidates. In some cases this may disadvantage candidates.

Any help given to a candidate should be noted on the Supervisor's Report. Supervisors are reminded that help should **not** be given with the recording of results, graphical work or analysis.

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

Comments on specific questions

Question 1

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

(a) (ii) Many candidates correctly stated a value of L in range, but it was not always given to the nearest millimetre. A few candidates omitted the units or gave inconsistent units e.g. 395 m.

(b) (iv) Candidates found it difficult to correctly state a value for I in range and with a consistent unit. A common error was to use an inconsistent unit e.g. 35 A.

(c) Most candidates were able to collect six different sets of values of x and I. Some candidates needed assistance from the Supervisor whilst other candidates stated results that showed an incorrect trend.

About half the candidates extended their range of x values to 30.0 cm or more. Many candidates increased their values from x = 10.0 cm in intervals of 5.0 cm up to 35 cm and did not take full advantage of the length of wire made available to them.

Some candidates were awarded credit for using the correct column headings in their tables, giving both the quantity recorded and a suitable unit for each quantity, with the two separated by a solidus or with the units in brackets. Many candidates either omitted the units or separating mark for $1/I$. Some candidates stated the wrong units for $1/I$, e.g. A instead of A^{-1}.

Some candidates recorded all their raw values for I to the nearest 0.1 mA, gaining credit. Some weaker candidates incorrectly stated their I values to the nearest A or presented trailing zeros to a greater precision than 0.1 mA when the measuring instrument (ammeter) provided can be read only to the nearest 0.1 mA.

Many candidates recorded their calculated values for $1/I$ to an appropriate number of significant figures dependent on the number of significant figures used in their current readings. Some candidates either stated too many significant figures or gave the calculated value to one significant figure, especially if the value was very small.

Most candidates calculated values for $1/I$ correctly. A few rounded their answers incorrectly and could not gain credit.

(d) (i) The size and scale of the graph axes chosen was varied. It is expected that the points plotted occupy more than half the graph grid available and the scale is easy to read. A large number of candidates drew awkward scales on the x-axis (multiples of 3 and 30 were common). This often also led to the loss of credit for plotting or for incorrect read-offs for the gradient and intercept because the scale was difficult to use correctly.

Many candidates gained credit for plotting their tabulated readings correctly. A few candidates labelled the axes $1/I$ when in fact the values were something different (e.g. I). A few candidates plotted the wrong graph (e.g. x versus I). If a point seems anomalous, candidates should be encouraged to repeat the measurement to check that an error in recording has not been made. If such a point is ignored in assessing the line of best fit, the anomalous point should be labelled clearly, e.g. by circling the point.

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

Many candidates were awarded credit for the quality of their data. Candidates should be encouraged to re-check their readings experimentally if one or two lie far away from the line of best fit.

(ii) Some candidates were able to draw carefully considered lines of best fit, but others joined the first and last points on the graph regardless of the distribution of the other points. There should always be a balanced distribution of points either side of the line along the entire length. Many lines needed rotation to get a better fit, or an anomalous point needed to be identified to justify the line drawn. Some candidates lost credit for lines that were kinked in the middle (candidates used too small a ruler), by drawing a double line (broken pencil tip) or by drawing freehand lines without the aid of a ruler.

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

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

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

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

Candidates found it difficult to record values with consistent units for both P (e.g. $A^{-1}\,m^{-1}$) and Q (e.g. A^{-1}).

(f) (ii) A small number of candidates calculated R in range. A large number of answers included power of ten errors stemming from candidates stating their currents in A (instead of mA) or making an error when converting cm into m.

Question 2

In this question, candidates were required to investigate the position of a wooden strip with several forces acting on it.

(a) (ii) Many candidates correctly recorded a value for C in range and with a unit.

(iii) Most candidates correctly recorded d in range and with consistent units but not always to the nearest millimetre. Some candidates stated inconsistent units or omitted units in the answer.

(iv) The majority of candidates calculated (C–d) correctly.

(b) (ii) Candidates recorded values of θ with a unit and should have given the value to the nearest degree. Many candidates incorrectly stated their value of angle to the nearest tenth of a degree when the protractor used to measure the angle had a scale that could be read to the nearest degree.

(iii) Most candidates were familiar with the equation for calculating percentage uncertainty. A few candidates made too small an estimate of the absolute uncertainty in the value of θ, typically 1° (the smallest scale division). Given that it was awkward to place a protractor near to the wooden strip and stand, leading to parallax error, a larger absolute uncertainty was required for this measurement. Some candidates repeated their readings and correctly gave the uncertainty in θ as half the range, while other candidates did not halve the range.

(c) Many candidates calculated ($\tan\theta$ –1) correctly. Some candidates incorrectly calculated the value of $\tan(\theta - 1)$. Many candidates stated their calculated value to an appropriate number of significant figures.

(d) The majority of candidates recorded a second value of d and a second value of θ.

Most candidates recorded a value for θ which was larger than θ for the shorter d.

(e) (i) Many candidates were able to calculate k for the two sets of data, showing their working clearly. A common error was to incorrectly rearrange the equation, e.g. using (C–d)/($\tan\theta$ –1) instead of ($\tan\theta$ –1) × (C–d).

(ii) Some candidates calculated the percentage difference between their two values of k, and then tested it against a specified percentage uncertainty, either taken from **(b)(iii)** or estimated themselves. This was accepted if the value was a reasonable reflection of the percentage uncertainty of this experiment. Candidates should justify any criterion provided above 20%. Many candidates omitted any sort of criterion. General statements such as “this is valid because the values are close to each other” were not credited.

(f) Many candidates recognised that two sets of data were insufficient to draw a valid conclusion. Many candidates stated that the angle was difficult to judge because of parallax error. Common valid solutions to these problems were to take more readings and plot a graph, and to add a scale to the wooden strip.

Credit is not given for suggestions that could be carried out in the original experiment, such as repeating measurements. Vague or generic answers such as 'too few readings', 'difficult to measure θ' (without stating a reason), 'systematic error', 'parallax error' (on its own without stating what measurement would be affected), 'air conditioning', 'turn off air con', 'faulty apparatus', 'use a set square' or 'use an assistant' cannot be given credit. Many improvements could not be credited because they were not specific enough or relied heavily on automatic/robotic devices. Other suggestions could not gain credit unless there was detailed clarification. For example, lubricating the pulley required some reference to which part (the axle, not the surface of the pulley wheel) and using a horizontal ruler needed some detail to describe how to check that the ruler was horizontal.

The key to this section is for candidates to identify genuine problems associated with setting up this experiment and in obtaining readings. Candidates are encouraged to suggest detailed practical solutions that either improve technique or give more reliable data.

PHYSICS

Paper 9702/41
A Level Structured Questions

Key messages

- Candidates often find it difficult to present a logical reasoned explanation. To develop this skill, Centres need to prepare candidates using exercises that involve a range of different explanations. Whilst explanations should be first taught in the context of the topic in which they naturally arise, there is merit to having a session that concentrates on explanations across a range of different topics as part of examination preparation.

- Some questions give an instruction such as "use your answer from..." To be awarded full credit for the answer, it is essential that the instruction is followed. Candidates should be encouraged to read the question carefully and follow any specific instructions relating to the required answer.

- A key part of preparing for any examination is experience of previous papers and mark schemes. This will enable candidates to learn the key words needed in definitions and also the correct use for similar terms such as nucleon, nucleus, nuclei etc.

General comments

Definitions have clearly been learnt well. Some candidates were not able to apply their knowledge to less familiar situations successfully. Candidates should be reminded of the need for precision in explanations, for instance not using the term particle when they mean atom or molecule, and not talking about the graph when they mean a specific line on a graph.

In general terms, candidates scored well on the traditional questions and found some questions on the newer material, such as **Question 12**, more difficult. Working was nearly always shown, which is encouraging. The use of language to make answers clear was very good in general and better than in previous series.

Comments on specific questions

Question 1

(a) Many candidates missed at least one of the key points as to why gravitational potential is negative; they either did not state that it is zero at infinity or that gravitational forces are attractive. Most candidates stated the definition of gravitational potential, but more than this was required.

(b) (i) Weaker candidates were able only to work out the change in potential, or divided by mass instead of multiplying by mass. Some used GM/r here, incorrectly using the mass of the rock. Many candidates stated that the change was a decrease. It is possible that these candidates were thinking of gravitational potential energy rather than kinetic energy.

(ii) This question was challenging. Many candidates used the change in potential they had worked out in **(b)(i)** or the potential at just one point on the graph. Weaker candidates again incorrectly applied GM/r. The idea that the rock needed to reach only the point where the field is zero was not appreciated by a large number of candidates.

Question 2

(a) Generally candidates scored well on this question. Some of the assumptions that were given were not awarded credit because of a lack of precision. Candidates would benefit from learning these assumptions carefully. There are no marks available for giving the assumptions already in the stem. Some weaker candidates referred to the gas laws or the ideal gas equation.

(b) (i) Most candidates were awarded credit. Some were not awarded credit because they used the wrong value of u or because they tried to add the mass of the electrons to that of u. Using the Avogadro constant was the most common way of arriving at the answer.

(ii) Candidates scored well here and many correctly equated the formula given to them with the kinetic energy formula. There were many power-of-ten errors where candidates used the mass of the α-particle in g rather than kg. Another relatively common error was to forget to take the square root at the end. Very few candidates did not convert the temperature into kelvin.

Question 3

(a) Most candidates knew the definition of simple harmonic motion and this was generally well-answered. A common mistake was to say "equilibrium" instead of "equilibrium position".

(b) Most candidates realised that the fact the graph was not a straight line meant that the object could not be undergoing simple harmonic motion. Very few realised that the magnitudes of the maximum displacements/accelerations were different. It was not enough just to say that 'displacement' was different – the word 'maximum' was essential. Many responses gave the same point twice, for example that the line was not straight and the acceleration is not proportional to the displacement.

(c) (i) This was well answered. A small number of candidates lost credit due to a reading error from the graph.

(ii) Most candidates knew the correct formula here, although weaker candidates forgot to square ω. Common errors were to use the value of 1.35 cm as the maximum displacement and a power-of-ten error due to forgetting to convert cm into m.

(iii) This question produced a range of answers. Many candidates did not use three whole periods for the calculation. Some candidates subtracted the amplitudes before squaring.

Question 4

(a) (i) Most candidates were awarded full credit. A small number thought that *c* refers to the speed of light, and this is incorrect physics which cannot be awarded credit.

(ii) Most candidates stated 'intensity reflection coefficient' for α. Some candidates who explained the ratio had it upside down, or included the transmitted intensity instead of the reflected intensity or incident intensity. It is important for candidates to use the word intensity here, rather than general terms like 'amount'. The meaning of *Z* was generally well explained.

(b) This was a challenging calculation. Some candidates did not appreciate they had calculated the reflected intensity and needed to subtract from 1 in order to find the transmitted intensity.

Question 5

(a) (i) Some candidates missed this question. Candidates should take care to check that they have answered all questions, perhaps by looking for the numbers of marks in brackets on the right-hand side.

(ii) Candidates were generally able to convert the values from the graph into binary. Some weaker candidates did not understand what a binary/digital number is. Some candidates did not state complete four-bit digital numbers (which is important in communications). The non-integer values should be rounded down.

(b) This question was found to be difficult. The idea of converting an analogue signal to a digital one is difficult for candidates and they do not always put steps on the graph. Some candidates redrew the original analogue signal.

(c) Some candidates clearly understood this well. Some suggested incorrect methods, such as the use of regenerators or repeaters. Many suggestions were not explained.

Question 6

Candidates often find drawing graphs difficult, and these graphs were generally not well drawn. Some candidates did not know how to show the variation of potential and field strength with distance correctly. Some of those that did understand the physics drew the lines without paying careful attention to the scales. Candidates would benefit from taking much more care to draw lines more accurately. Some candidates lost credit because they missed out the appropriate horizontal lines from a distance of 0 to a distance of R.

Question 7

(a) The difference between systematic error and random error was not well understood, and candidates would benefit from further study of this topic. The scatter of the points is not relevant to the idea of systematic error. Candidates should be encouraged to be specific when describing graphs: there is a difference between referring to the graph and to the line of best fit.

(b) Many candidates attempted to find the capacitance without drawing a line of best fit and this was not awarded credit. A significant number also forced the line through the origin when it clearly did not go there; the existence of a systematic error had already been indicated. There were some errors with powers of ten.

(c) The majority of responses gained credit for knowing or deducing that energy = $\frac{1}{2}CV^2$. It was common for candidates to lose credit when the difference of two voltages was calculated and then squared, as opposed to correctly squaring the voltages and then finding the difference.

Question 8

(a) Many candidates did not say that the open loop gain of the amplifier is high. Another common mistake was to forget to say why the two inputs had to be approximately the same, to prevent saturation. Some candidates mixed up the inverting and non-inverting inputs.

(b) Candidates needed to explicitly state that the current through the resistor with resistance R_1 is the same as that in the R_2 resistor. Very few started with the alternative method, which was to say that the input resistance of the op-amp is very large. Other errors were in omitting the minus sign or stating/deriving an incorrect gain equation.

(c) There were many good circuit diagrams here. If candidates choose to include a protective diode, it needs to have the correct polarity otherwise the circuit will not work. Candidates who connected the output of the op-amp to the switch could not be awarded credit. Some candidates showed breaks in their circuits, so the circuit would not function.

Question 9

(a) This was a straightforward introductory question on the Hall effect. Candidates found it difficult to identify which was the dimension t and some responses had multiplied two or three of the dimensions together.

(b) When calculating the Hall voltage, some candidates were confused by the number of free electrons per unit volume, and multiplied this by the volume of the aluminium slice.

Question 10

(a) There were some excellent responses here. Weaker candidates struggled to put together coherent explanations. They often missed important points, such as giving the reason for the existence of an induced e.m.f. Many responses would benefit from clearly stating where something is taking place, such as "the magnetic flux in the core changes".

(b) Many candidates gave incorrect explanations based upon aluminium being magnetic and attracting the magnet towards it hence 'slowing it down'. The idea of the magnet slowing down was common. Candidates needed to realise that the acceleration is reduced, but the magnet was accelerating until terminal velocity and never slowing down.

Question 11

(a) This calculation of frequency was usually correct. There were some errors in reading from the graph and also occasional power of ten errors.

(b) Candidates who had a good understanding of alternating current were able to see immediately that the mean current is zero. Other candidates either did not understand alternating current or perhaps did not have the confidence to write zero as an answer. The idea that the mean current is zero is fundamental to the concept of alternating current.

(c) This was much more successfully answered than **(b)**. A few weaker candidates multiplied by $\sqrt{2}$ rather than dividing.

(d) Candidates found this question difficult. Some candidates stated incorrect equations such as $E = P / t$. Others were confused by the difference between energy and power.

Question 12

(a) Candidates' responses often did not demonstrate that they understood that it was the close proximity of the atoms and their interaction that causes the energy levels to split and spread.

(b) Most candidates were able to obtain at least partial credit for this question. The concept of electrons going from the valence band to the conduction band was well understood, but the ideas of making the electrons free to move and leaving holes in the valence band were not as well understood. Candidates often did not describe the origin of the energy to promote the electrons.

Question 13

(a) Candidates were generally awarded partial credit for this question. They often understood the idea of background radiation adding to the count rate. It was uncommon for credit to be awarded for any of the other possible reasons. Mention of decay being spontaneous and random is not relevant; neither is the activity changing over time. The shielding does absorb radiation, but the count rate from the detector in the position shown would be the same even if the shielding were not there, so its existence does not influence the measured count rate.

(b) There were many correct calculations here. A common error was to begin by subtracting the two activities.

(c) A large proportion of candidates answered this correctly, showing that they were able to make deductions about a new situation.

PHYSICS

Paper 9702/42
A Level Structured Questions

Key messages

- Candidates often find it difficult to present a logical reasoned explanation. To develop this skill, Centres need to prepare candidates using exercises that involve a range of different explanations. Whilst explanations should be first taught in the context of the topic in which they naturally arise, there is merit to having a session that concentrates on explanations across a range of different topics as part of examination preparation.

- Some questions give an instruction such as "use your answer from..." To be awarded full credit for the answer, it is essential that the instruction is followed. Candidates should be encouraged to read the question carefully and follow any specific instructions relating to the required answer.

- A key part of preparing for any examination is experience of previous papers and mark schemes. This will enable candidates to learn the key words needed in definitions and also the correct use for similar terms such as nucleon, nucleus, nuclei etc.

General comments

The introduction of new material in the revised syllabus and the re-ordering of the subject material appear to have led to a significant number of candidates being unable to give answers to some questions. Amongst these candidates, many did not attempt answers but left the answer spaces blank. A good performance cannot be achieved unless the whole syllabus is studied and all questions on the paper are attempted.

As in previous years, candidates found the numerical parts of questions to be much easier than the descriptive sections. Questions on the newer topics on the syllabus illustrated that many weaker candidates had only a rather superficial knowledge of the subject matter.

There was little evidence to suggest that well-prepared candidates did not have sufficient time to complete their answers.

Comments on specific questions

Question 1

(a) (i) Many answers did not make any reference to gravitational force, but instead were based solely on equal angular speeds. Where gravitational force was discussed, many candidates gave the incorrect impression that there are two forces (gravitational and centripetal) acting on each star.

(ii) Generally, this calculation was completed successfully. A minority did not convert correctly the time in years to the time in seconds. The practice of equating one year to (12×30) days should be discouraged as it leads to inaccurate answers.

(b) (i) Candidates who equated the product of mass and centripetal acceleration for the two stars usually arrived at the correct conclusion. Those who attempted to equate gravitational forces were often unsuccessful because they substituted distances other than the separation of the two stars.

(ii) There were fewer correct responses here. Candidates who were able to set up a correct equation frequently substituted incorrect distances into their equation. There was much confusion between the distance between the stars and the distance to point P. Some candidates gave answers as little as a few kilograms, which could have been identified as incorrect by taking a moment to consider the order of magnitude of the answer.

Question 2

(a) (i) A formal statement relating the Avogadro constant to the number of atoms in 12 g of carbon-12 was seen rarely. Many candidates just gave the number or described it in terms of molecules or particles.

(ii) A reference to 'amount of substance' was given in a minority of scripts. Generally, the discussion was based around how to determine the number of mol in a sample.

(b) The great majority of answers were correct, with numerical values of the relevant quantities substituted into the equation of state for the gas.

(c) (i) Very few realised that the pressure would be proportional to *n* and thus had a very simple calculation. Most solutions were based on finding the new value for *n* and then substituting this into the full equation of state. This could provide a correct answer but the method was prone to errors. A common error was to attempt to calculate a new volume for the gas in the cylinder.

(ii) Many candidates achieved the correct result but made difficulties for themselves by calculating the number of molecules in 150 mol and in 142.5 mol. Candidates should be encouraged to be conscious of rounding numbers too early in a calculation. If 142.5 mol is rounded to 143 mol or 140 mol, a correct answer cannot be obtained.

Question 3

(a) Incomplete answers frequently stated that there is no heat transfer, rather than no net transfer of energy. The most common incorrect statements were based on the two bodies having equal (thermal) energies.

(b) Appropriate thermometers to use in these circumstances were known by only a minority of candidates. Weaker candidates often suggested using a liquid-in-glass thermometer. Others did not appreciate that a thermistor could not be used for the temperature of the Bunsen flame.

(c) (i) There were many correct answers with only a small number of candidates attempting to add 273.2 to the difference.

(ii) Despite having given the answer correctly to one decimal place in **(i)**, many candidates then gave this answer to either two or zero decimal places.

Question 4

(a) (i) This question was generally answered correctly with very few inappropriate values for the time period.

(ii) The appropriate expression for energy was quoted in a majority of scripts. A common mistake was associated with the power of ten for either the amplitude or, less frequently, the mass.

(b) Candidates found it difficult to sketch an appropriate curve showing the relevant features. The curvature, the position of the peak and the range of frequency were all important features which rarely received sufficient attention. Many candidates drew a straight line, suggesting that they had little understanding of this topic.

(c) Many curves either did not have a flatter peak or showed the two lines crossing.

Question 5

(a) There were many correct statements of this formal definition. Weaker candidates tended to confuse amplitude and displacement, or carrier wave and information wave.

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

(ii) Only rarely was the maximum audio frequency identified. Common answers were 198 kHz and 203 kHz, which are far above the maximum audible frequency.

(c) (i) Most answers involved a correct expression for attenuation in dB. There was some confusion with many giving the answer to **(c)(ii)** here.

(ii) Those candidates who arrived at the correct result in **(c)(i)** usually then made a good attempt at this question. Some candidates carried out correct calculations but then came to an incorrect conclusion as to whether the system would function.

Question 6

(a) Many answers were not based on the pattern of field lines, as was required by the question. Many responses were a paraphrase of the question.

(b) (i) Generally, this question was answered well. The most common mistakes were either to use an inappropriate value for the charge on a proton or to double the charge or mass, rather than take the square of the quantity.

(ii) It was expected that reference would be made to the ratio in **(i)** so that a comparison between the two forces could be made. Often the gravitational force was stated to be negligible without reference to the ratio. In cases such as this where the question asks for reference to be made to a previous answer, this is essential in order for credit to be awarded.

Question 7

(a) Most candidates could give one use (usually the storage of energy) but few were given credit for two because it was common to find that the second use was in smoothing. This could not be awarded credit because it was given in the question. Blocking d.c. and timing circuits were the most usual alternatives.

(b) (i) Despite being given the relevant equations on page 3, this calculation presented a real challenge to weaker candidates. A common error was to equate the reciprocals of the components to the total capacitance, rather than to its reciprocal. Candidates would benefit from further practice using the equations for combining capacitances.

(ii) Many candidates did not realise that the total charge is determined using the total capacitance and the applied potential difference.

(iii) This question tested the concept of charge conservation. Few candidates realised that the total charge would be received by the capacitors in series and that the capacitors in parallel would then share this charge equally. Frequently, answers did not appear to have been given with reference to the answer given in **(b)(ii)**, with many having greater charges on the individual capacitors than the total charge.

Question 8

(a) (i) The majority of candidates gave the correct expression or described the relationship as a ratio. Some weaker candidates described the gain as a 'difference' or attempted to explain infinite gain.

(ii) Very few candidates were able to describe any link between change in input voltage and the subsequent change in output voltage. Many attempts could not be recognised as being relevant to slew rate.

(b) This calculation was completed successfully by most candidates. Some candidates inappropriately used an expression for the gain of an inverting amplifier.

(c) There were very few correctly shaped graphs. Weaker candidates often copied the graph of Fig. 8.2, with little regard for the maximum output potential.

Question 9

The Hall effect is a new topic on the syllabus, and many scripts showed that candidates were not able to demonstrate a sufficient understanding of the topic. Candidates would benefit from further study of the Hall effect and practice of questions on the effect.

(a) (i) Many candidates did not know what is represented by *n*. Many stated an irrelevant answer such as number of turns of wire or number of lines of magnetic field. Only a small number of stronger candidates made mention of free electrons or number density.

(ii) There were few correct answers. Some candidates quoted an area, rather than a distance, as being represented by *t*.

(b) (i) Most answers could not be recognised as being relevant to the question. It was common to see answers in terms of electrons moving from a valence band to a conduction band. It was expected that candidates would refer to the difference in the number density of charge carriers and the effect this has on the Hall voltage, as seen in the given formula.

(ii) Few candidates had any appreciation of the concept of a hole. Statements such as “the holes in the solid will mean that electrons will have more space in which to move” were relatively common. For full credit, candidates needed to consider the direction of the force due to the magnetic field on holes and on free electrons. Many candidates did not make any reference to the magnetic field.

Question 10

(a) Candidates recognised that the question referred to a change in flux linkage and an induced e.m.f. Many answers made no reference to the moving rod. Instead, it was stated that the change in flux in coil A cut coil B or coil B moved. Some answers involved the rod cutting the flux in coil A, rather than changing the flux in the coil.

(b) Many diagrams appeared to show the inverse of Fig. 10.2, and candidates who drew this type of graph did not appear to understand the relationship between the gradient of a current/time graph and rate of change of flux and hence induced e.m.f. Stronger candidates clearly showed a peak voltmeter reading where there was a sudden change in current.

Question 11

(a) The majority of answers were correct but a significant number of candidates did not attempt this question.

(b) There were many correct calculations. A significant minority calculated correctly the r.m.s.voltage but then gave that result as the r.m.s. current.

(c) (i) Although the majority of answers were correct, a significant number of diagrams showed the capacitor in series with the load.

(ii) Most candidates were awarded some credit for drawing a line from the peak to the 3 V mark on the given line. Very few gave a version for full-wave rectification and the line drawn was often of an inappropriate shape, with little regard for the peaks that had been drawn on Fig. 11.2 or for the discharge of the smoothing capacitor.

Question 12

Many candidates did not demonstrate an appreciation of the production or properties of X-rays. There was confusion between X-ray production and the photoelectric effect.

(a) (i) The most usual explanation was based on electrons arriving at the anode with a range of energies and thus giving rise to a range of wavelengths. Alternatively, the electrons had a range of accelerations as they moved from the cathode. Very rarely was there a clear statement that an X-ray photon is produced when the electron is accelerated.

(ii) Some candidates attempted an explanation in terms of the photoelectric effect. Very few attributed the cut-off to a single electron giving all of its energy to produce one photon in a single collision.

(iii) An explanation was given frequently in terms of a resonance effect or some form of interference effect. Very few attributed the peaks to the de-excitation of electrons in atoms in the metal of the anode.

(b) (i) Many candidates were able to give an acceptable answer. Some candidates suggested lead and others gave no indication that the material would be in the form of a sheet or foil.

(ii) Many candidates attempted to explain the situation in terms of increased dosage to the patient without mentioning that the body would absorb these wavelengths of radiation. In some answers, it was suggested that these wavelengths were of 'no use' or caused poor contrast.

Question 13

(a) There were many answers giving details of the properties of gamma radiation, but it was common to find that it was not stated that the radiation is an electromagnetic wave.

(b) A large number of candidates did not draw a line of best fit for the points on the graph. Instead, the analysis was often based on two points on the graph which were not necessarily well spaced. Some weaker candidates substituted values for $\ln C$ from the graph into the decay equation as if they were values for C.

(c) The question asked for a comparison between aluminium and lead, and many answers did not give a comparison. Rather, there was a statement to the effect that either lead absorbs the radiation or that the radiation penetrates the aluminium. Consequently a conclusion that μ would be less for aluminium could not be reached.

PHYSICS

Paper 9702/43
A Level Structured Questions

Key messages

- Candidates often find it difficult to present a logical reasoned explanation. To develop this skill, Centres need to prepare candidates using exercises that involve a range of different explanations. Whilst explanations should be first taught in the context of the topic in which they naturally arise, there is merit to having a session that concentrates on explanations across a range of different topics as part of examination preparation.

- Some questions give an instruction such as "use your answer from..." To be awarded full credit for the answer, it is essential that the instruction is followed. Candidates should be encouraged to read the question carefully and follow any specific instructions relating to the required answer.

- A key part of preparing for any examination is experience of previous papers and mark schemes. This will enable candidates to learn the key words needed in definitions and also the correct use for similar terms such as nucleon, nucleus, nuclei etc.

General comments

Definitions have clearly been learnt well. Some candidates were not able to apply their knowledge to less familiar situations successfully. Candidates should be reminded of the need for precision in explanations, for instance not using the term particle when they mean atom or molecule, and not talking about the graph when they mean a specific line on a graph.

In general terms, candidates scored well on the traditional questions and found some questions on the newer material, such as **Question 12**, more difficult. Working was nearly always shown, which is encouraging. The use of language to make answers clear was very good in general and better than in previous series.

Comments on specific questions

Question 1

(a) Many candidates missed at least one of the key points as to why gravitational potential is negative; they either did not state that it is zero at infinity or that gravitational forces are attractive. Most candidates stated the definition of gravitational potential, but more than this was required.

(b) (i) Weaker candidates were able only to work out the change in potential, or divided by mass instead of multiplying by mass. Some used GM/r here, incorrectly using the mass of the rock. Many candidates stated that the change was a decrease. It is possible that these candidates were thinking of gravitational potential energy rather than kinetic energy.

(ii) This question was challenging. Many candidates used the change in potential they had worked out in **(b)(i)** or the potential at just one point on the graph. Weaker candidates again incorrectly applied GM/r. The idea that the rock needed to reach only the point where the field is zero was not appreciated by a large number of candidates.

Question 2

(a) Generally candidates scored well on this question. Some of the assumptions that were given were not awarded credit because of a lack of precision. Candidates would benefit from learning these assumptions carefully. There are no marks available for giving the assumptions already in the stem. Some weaker candidates referred to the gas laws or the ideal gas equation.

(b) (i) Most candidates were awarded credit. Some were not awarded credit because they used the wrong value of u or because they tried to add the mass of the electrons to that of u. Using the Avogadro constant was the most common way of arriving at the answer.

(ii) Candidates scored well here and many correctly equated the formula given to them with the kinetic energy formula. There were many power-of-ten errors where candidates used the mass of the α-particle in g rather than kg. Another relatively common error was to forget to take the square root at the end. Very few candidates did not convert the temperature into kelvin.

Question 3

(a) Most candidates knew the definition of simple harmonic motion and this was generally well-answered. A common mistake was to say "equilibrium" instead of "equilibrium position".

(b) Most candidates realised that the fact the graph was not a straight line meant that the object could not be undergoing simple harmonic motion. Very few realised that the magnitudes of the maximum displacements/accelerations were different. It was not enough just to say that 'displacement' was different – the word 'maximum' was essential. Many responses gave the same point twice, for example that the line was not straight and the acceleration is not proportional to the displacement.

(c) (i) This was well answered. A small number of candidates lost credit due to a reading error from the graph.

(ii) Most candidates knew the correct formula here, although weaker candidates forgot to square ω. Common errors were to use the value of 1.35 cm as the maximum displacement and a power-of-ten error due to forgetting to convert cm into m.

(iii) This question produced a range of answers. Many candidates did not use three whole periods for the calculation. Some candidates subtracted the amplitudes before squaring.

Question 4

(a) (i) Most candidates were awarded full credit. A small number thought that *c* refers to the speed of light, and this is incorrect physics which cannot be awarded credit.

(ii) Most candidates stated 'intensity reflection coefficient' for α. Some candidates who explained the ratio had it upside down, or included the transmitted intensity instead of the reflected intensity or incident intensity. It is important for candidates to use the word intensity here, rather than general terms like 'amount'. The meaning of *Z* was generally well explained.

(b) This was a challenging calculation. Some candidates did not appreciate they had calculated the reflected intensity and needed to subtract from 1 in order to find the transmitted intensity.

Question 5

(a) (i) Some candidates missed this question. Candidates should take care to check that they have answered all questions, perhaps by looking for the numbers of marks in brackets on the right-hand side.

(ii) Candidates were generally able to convert the values from the graph into binary. Some weaker candidates did not understand what a binary/digital number is. Some candidates did not state complete four-bit digital numbers (which is important in communications). The non-integer values should be rounded down.

(b) This question was found to be difficult. The idea of converting an analogue signal to a digital one is difficult for candidates and they do not always put steps on the graph. Some candidates redrew the original analogue signal.

(c) Some candidates clearly understood this well. Some suggested incorrect methods, such as the use of regenerators or repeaters. Many suggestions were not explained.

Question 6

Candidates often find drawing graphs difficult, and these graphs were generally not well drawn. Some candidates did not know how to show the variation of potential and field strength with distance correctly. Some of those that did understand the physics drew the lines without paying careful attention to the scales. Candidates would benefit from taking much more care to draw lines more accurately. Some candidates lost credit because they missed out the appropriate horizontal lines from a distance of 0 to a distance of R.

Question 7

(a) The difference between systematic error and random error was not well understood, and candidates would benefit from further study of this topic. The scatter of the points is not relevant to the idea of systematic error. Candidates should be encouraged to be specific when describing graphs: there is a difference between referring to the graph and to the line of best fit.

(b) Many candidates attempted to find the capacitance without drawing a line of best fit and this was not awarded credit. A significant number also forced the line through the origin when it clearly did not go there; the existence of a systematic error had already been indicated. There were some errors with powers of ten.

(c) The majority of responses gained credit for knowing or deducing that energy = $\frac{1}{2}CV^2$. It was common for candidates to lose credit when the difference of two voltages was calculated and then squared, as opposed to correctly squaring the voltages and then finding the difference.

Question 8

(a) Many candidates did not say that the open loop gain of the amplifier is high. Another common mistake was to forget to say why the two inputs had to be approximately the same, to prevent saturation. Some candidates mixed up the inverting and non-inverting inputs.

(b) Candidates needed to explicitly state that the current through the resistor with resistance R_1 is the same as that in the R_2 resistor. Very few started with the alternative method, which was to say that the input resistance of the op-amp is very large. Other errors were in omitting the minus sign or stating/deriving an incorrect gain equation.

(c) There were many good circuit diagrams here. If candidates choose to include a protective diode, it needs to have the correct polarity otherwise the circuit will not work. Candidates who connected the output of the op-amp to the switch could not be awarded credit. Some candidates showed breaks in their circuits, so the circuit would not function.

Question 9

(a) This was a straightforward introductory question on the Hall effect. Candidates found it difficult to identify which was the dimension t and some responses had multiplied two or three of the dimensions together.

(b) When calculating the Hall voltage, some candidates were confused by the number of free electrons per unit volume, and multiplied this by the volume of the aluminium slice.

Question 10

(a) There were some excellent responses here. Weaker candidates struggled to put together coherent explanations. They often missed important points, such as giving the reason for the existence of an induced e.m.f. Many responses would benefit from clearly stating where something is taking place, such as “the magnetic flux in the core changes”.

(b) Many candidates gave incorrect explanations based upon aluminium being magnetic and attracting the magnet towards it hence 'slowing it down'. The idea of the magnet slowing down was common. Candidates needed to realise that the acceleration is reduced, but the magnet was accelerating until terminal velocity and never slowing down.

Question 11

(a) This calculation of frequency was usually correct. There were some errors in reading from the graph and also occasional power of ten errors.

(b) Candidates who had a good understanding of alternating current were able to see immediately that the mean current is zero. Other candidates either did not understand alternating current or perhaps did not have the confidence to write zero as an answer. The idea that the mean current is zero is fundamental to the concept of alternating current.

(c) This was much more successfully answered than **(b)**. A few weaker candidates multiplied by $\sqrt{2}$ rather than dividing.

(d) Candidates found this question difficult. Some candidates stated incorrect equations such as $E = P / t$. Others were confused by the difference between energy and power.

Question 12

(a) Candidates' responses often did not demonstrate that they understood that it was the close proximity of the atoms and their interaction that causes the energy levels to split and spread.

(b) Most candidates were able to obtain at least partial credit for this question. The concept of electrons going from the valence band to the conduction band was well understood, but the ideas of making the electrons free to move and leaving holes in the valence band were not as well understood. Candidates often did not describe the origin of the energy to promote the electrons.

Question 13

(a) Candidates were generally awarded partial credit for this question. They often understood the idea of background radiation adding to the count rate. It was uncommon for credit to be awarded for any of the other possible reasons. Mention of decay being spontaneous and random is not relevant; neither is the activity changing over time. The shielding does absorb radiation, but the count rate from the detector in the position shown would be the same even if the shielding were not there, so its existence does not influence the measured count rate.

(b) There were many correct calculations here. A common error was to begin by subtracting the two activities.

(c) A large proportion of candidates answered this correctly, showing that they were able to make deductions about a new situation.

PHYSICS

Paper 9702/51
Planning, Analysis and Evaluation

Key messages

- In **Question 1**, candidates' responses should include detailed explanations of experimental procedures, such as control of variables, measurements to be taken and analysis of data.
- Graphical work should be carefully attempted and checked. Candidates should use a sharp pencil when plotting points and use a transparent 30 cm ruler when drawing the line of best fit and the worst acceptable line; care is also needed when reading information from the graph.
- The numerical answers towards the end of **Question 2** require candidates to show all their working, particularly when determining uncertainties. A full understanding of significant figures is required.
- The practical skills required for this paper should be developed and practised over a period of time with a 'hands on' approach.

General comments

The vast majority of candidates completed the paper in the time available. Most scripts were clearly written. Writing in black or dark blue ink makes the scripts easier to read.

In **Question 1**, candidates did not always describe the method in the necessary detail. Circuit diagrams could also be improved. In some answers there was a lot of irrelevant writing; it is advisable that candidates should think carefully about the experiment following the points given on the question paper and to imagine how they would perform the experiment in the laboratory.

In **Question 2**, graphs were well drawn with points and error bars easily identifiable. Candidates should be advised that, to gain the highest marks, the presentation of mathematical working requires a clear statement of the equation used and clear substitution of numbers, leading to the correct answer. Furthermore, the working has to be logical and readable.

It is clear that the stronger candidates have experienced a practical course where the skills required for this paper are developed and practised over a period of time with a 'hands on' approach. To assist Centres, Cambridge has produced practical support booklets which are available from the Teacher Support Site.

Comments on specific questions

Question 1

Candidates were required to investigate the characteristics of different light-emitting diodes (LEDs). They were to investigate the relationship between the minimum potential difference V across an LED and the wavelength λ of the light emitted by the LED for several different LEDs.

Many candidates were not awarded credit for identifying the dependent and independent variables. They often correctly chose the variables but interchanged them, i.e. V was selected as the independent variable. Most of these candidates received partial credit for stating that they would measure the p.d. across the LED. On this particular question there was no constant in the given relationship though many candidates stated current was to be kept constant.

Four marks are available for the methods of data collection. Credit was awarded for a correct, workable electric circuit. Candidates should be encouraged to use correct circuit symbols. Common errors included voltmeters connected in series or not connected across the LED, or no d.c. source shown. A significant number of candidates correctly placed a variable resistor in the circuit or labelled the power source as variable. Candidates should check the polarity: a mark for additional detail was available for showing the correct polarity of the power supply so that the diode was forward biased.

Many candidates thought that a light detector connected to a cathode-ray oscilloscope can measure the frequency (wavelength) of light, but this was not awarded credit. Stronger candidates selected a diffraction grating or Young's slits, gave good explanations and gained an additional detail mark for the correct equation to determine the wavelength. When quoting equations, candidates should define all the symbols used and should make the quantity being determined the subject of the equation.

The final mark for data collection was for the practical method of obtaining the minimum p.d. across the LED when it just lights. Many candidates did not state how they would use the circuit in order to measure the p.d. across the diode. It was expected that the p.d. would be increased slowly by the variable power source or by changing the resistance of the variable resistor until the LED just emits light. Candidates often described measuring the p.d. with a voltmeter but tended not to explain how the exact point when the LED just lights was achieved.

There are now three marks available for the analysis of data. The majority of candidates scored the first mark for identifying a graph to plot, though a few candidates did not convert the quantities to logarithms. Both logarithms to the base ten and natural logarithms were accepted. The determination of the value of n equal to the gradient was often given by candidates. To be awarded credit for determining constants, candidates must give the constant as the subject of the equation: $\log k = y$-intercept was not sufficient. Many candidates stated that the y-intercept would be zero; this would be true only if $k = 1$.

The additional detail section had a maximum of six marks that could be awarded. The marking points allowed candidates to broaden their answers and most obtained several of these marks. Candidates should be encouraged to write their plans including appropriate detail; often candidates' answers suggested that they did not have sufficient practical experience. Vague responses were not credited. Those candidates who have followed a 'hands on' practical course are generally much better placed to gain credit for additional detail. It is essential that candidates give detail relevant to the experiment in question rather than general 'textbook' rules for working in a laboratory.

Candidates should be made aware that the bland statement of "the experiment is repeated and an average is taken" is not awarded credit. More detail is required, such as "for the same wavelength, the experiment is repeated and V is recorded again and the average value of V is then determined".

Question 2

The question required candidates to analyse data given for how the extension e of a loaded wire depends on the diameter d of the wire.

(a) This question was generally answered well.

(b) Nearly all candidates were awarded credit for the column heading. The common mistake in the $1/d^2$ column was stating the first value to four significant figures. Since the raw data were given to two significant figures, it was expected that $1/d^2$ would be given to two or three significant figures. The majority of candidates calculated the absolute uncertainty correctly; a common error was not doubling the percentage uncertainty for d^2.

(c) (i) The majority of candidates scored full credit for the plotting of the data points with the corresponding error bars. Common reasons for loss of credit were vertical error bars and drawing large 'blobs' for the plotted points.

(ii) Both the line of best fit and worst acceptable line were generally drawn well. Candidates should clearly indicate the lines drawn.

(iii) Most candidates clearly demonstrated the points that they used to calculate the gradient. Candidates are improving in their ability to select points that are on the line rather than quoting values from the table, and most could choose a sensibly-sized triangle. A significant number of candidates had a power of ten error having not used the data from the axes correctly.

(d) (i) It is vital that the working for the answer is clearly shown. The equation should be quoted followed by correct substitution of numerical values, one of which must be the value of the gradient calculated in **(c)(iii)**. Many candidates did not give a correct unit, and several candidates did not give any unit. There were many variations such as $N\,m^{-1}$. Candidates should be encouraged to determine the correct unit from the equation.

(ii) There was good recognition that the percentage uncertainty in *E* was the sum of the percentage uncertainties of the three necessary components in the equation. Those candidates attempting to use a 'maximum/minimum' method tended to make mistakes by not clearly showing where their data has originated or by using incorrect combinations of maximum and minimum values.

(e) A number of candidates correctly realised that *e* was equal to the gradient/d^2 and determined the absolute uncertainty correctly. The calculated value of *e* needed to be quoted to two or three significant figures and be given with the correct power of ten, and its value needed to fall within a given range. Clear, logical working was required, and candidates who could not demonstrate their understanding by showing the method were not awarded credit. A large proportion of candidates were unable to give a correct solution to finding the absolute uncertainty in *e*. It was expected that appropriate equations would be used with substitution of data.

PHYSICS

Paper 9702/52
Planning, Analysis and Evaluation

Key messages

- In **Question 1**, candidates' responses should include detailed explanations of experimental procedures, such as control of variables, measurements to be taken and analysis of data.
- Graphical work should be carefully attempted and checked. Candidates should use a sharp pencil when plotting points and use a transparent 30 cm ruler when drawing the line of best fit and the worst acceptable line; care is also needed when reading information from the graph.
- The numerical answers towards the end of **Question 2** require candidates to show all their working, particularly when determining uncertainties. A full understanding of significant figures is required.
- The practical skills required for this paper should be developed and practised over a period of time with a 'hands on' approach.

General comments

The vast majority of candidates completed the paper in the time available. Most scripts were clearly written. Writing in black or dark blue ink makes the scripts easier to read.

In **Question 1**, candidates did not always describe the method in the necessary detail. The methods that candidates described to determine the acceleration often did not have enough detail and did not mention the appropriate measurements. In some answers there was a lot of irrelevant writing; it is advisable that candidates should think carefully about the experiment following the points given on the question paper and to imagine how they would perform the experiment in the laboratory.

In **Question 2**, graphs were well drawn with points and error bars easily identifiable. Candidates should be advised that, to gain the highest marks, the presentation of mathematical working requires a clear statement of the equation used and clear substitution of numbers, leading to the correct answer. Furthermore, the working has to be logical and readable.

It is clear that the stronger candidates have experienced a practical course where the skills required for this paper are developed and practised over a period of time with a 'hands on' approach. To assist Centres, Cambridge has produced practical support booklets which are available from the Teacher Support Site.

Comments on specific questions

Question 1

Candidates were required to investigate the relationship between the acceleration a of a trolley moving up an inclined plane and the angle θ of the plane when a force F is applied to the trolley. Some candidates did not read the question and designed experiments with the trolley rolling down the plane.

Most candidates gained credit for stating that θ was the independent variable and a was the dependent variable. A second mark was awarded for stating that F needed to be kept constant. An additional detail mark was available for stating that the mass of the trolley needed to be kept constant; candidates needed to be specific regarding which mass was being kept constant.

Four marks are available for the methods of data collection. Credit was available for a correct, labelled diagram indicating how the inclined plane could be supported and how the angle could be changed. Many candidates drew supports that would not have made the inclined plane stable. Often a number of distances were marked on the diagram but the start and end points were vague.

The third mark in this section was for describing a suitable method to determine the acceleration of the trolley. Candidates needed to explain how they would measure a suitable time interval. Additional detail marks were available for how an appropriate distance could be measured and for giving an appropriate equation to determine acceleration. Many candidates just stated the definition of acceleration which was not necessarily relevant to the method they had suggested. Where candidates suggest data logging procedures, clear explanations are needed of the required measurements. For example, if a piece of card is being used to interrupt a light beam, then this length of card needs to be measured with a ruler. The final mark in this section was for the method of obtaining the mass of the trolley which would be needed to determine *k*. It was expected that candidates would use a balance; "use a scale" was not considered to be sufficient.

There are now three marks available for the analysis of data. The majority of correct answers described plotting a graph of *a* against sin θ. A large number of candidates suggested a graph of *a* against θ and as a consequence could not gain any further credit in this section. Another mark was awarded for realising that the relationship would be valid if, from the appropriate graph, a straight line that did not pass through the origin was observed. Many candidates incorrectly assumed that the straight line would pass through the origin. To be awarded credit for determining constants, candidates must give the constant as the subject of the equation: *k* needed to be the subject of the equation that included the *y*-intercept. Many candidates did not work out the *y*-intercept correctly, with many incorrectly positioned negative signs.

The additional detail section had a maximum of six marks that could be awarded. The marking points allowed candidates to broaden their answers and a large number of the stronger candidates obtained several of these marks. Candidates should be encouraged to write their plans including appropriate detail; often candidates' answers suggested that they did not have sufficient practical experience. Vague responses were not credited. Those candidates who have followed a 'hands on' practical course are generally much better placed to gain credit for additional detail. It is essential that candidates give detail relevant to the experiment in question rather than general 'textbook' rules for working in a laboratory.

Candidates should be made aware that the bland statement of "the experiment is repeated and an average is taken" is not awarded credit. More detail is required, such as "for the same angle, the experiment is repeated, *a* is determined again and the average value of *a* is then found".

Question 2

The question required candidates to analyse data given for how the resistance *R* of a wire depends on the diameter *d* of the wire.

(a) This question was generally answered well.

(b) Nearly all candidates were awarded credit for the column heading. The common mistake in the $1/d^2$ column was stating the last value to four significant figures. Since the raw data were given to two significant figures, it was expected that $1/d^2$ would be given to two or three significant figures. The majority of calculated the absolute uncertainty correctly; a common error was not doubling the percentage uncertainty for d^2.

(c) (i) The majority of candidates scored full credit for the plotting of the data points with the corresponding error bars. Common reasons for loss of credit were vertical error bars and drawing large 'blobs' for the plotted points.

(ii) Both the line of best fit and worst acceptable line were generally drawn well. Candidates should clearly indicate the lines drawn.

(iii) Most candidates clearly demonstrated the points that they used to calculate the gradient. Candidates are improving in their ability to select points that are on the line rather than quoting values from the table, and most could choose a sensibly-sized triangle. A significant number of candidates had a power of ten error having not used the data from the axes correctly.

(d) (i) It is vital that the working for the answer is clearly shown. The equation should be quoted followed by correct substitution of numerical values, one of which must be the value of the gradient calculated in **(c)(iii)**. Many candidates did not give a correct unit, and several candidates did not give any unit. A number of candidates made a power of ten error in the gradient and so the value of ρ here had the wrong power of ten.

(ii) There was good recognition that the percentage uncertainty of ρ was the sum of the percentage uncertainties of the two necessary components in the equation. Those candidates attempting to use a 'maximum/minimum' method tended to make mistakes by not clearly showing where their data has originated or by using incorrect combinations of maximum and minimum values.

(e) A number of candidates correctly realised that R was equal to the gradient/d^2 and determined the absolute uncertainty correctly. The calculated value of R needed to be quoted to two or three significant figures and needed to be in a specific range. A number of candidates did not allow for d being measured in millimetres. Clear, logical working was required, and candidates who could not demonstrate their understanding by showing the method were not awarded credit. Some candidates were unable to give a correct solution to finding the absolute uncertainty in R. It was expected that appropriate equations would be used with substitution of data.

PHYSICS

Paper 9702/53
Planning, Analysis and Evaluation

Key messages

- In **Question 1**, candidates' responses should include detailed explanations of experimental procedures, such as control of variables, measurements to be taken and analysis of data.
- Graphical work should be carefully attempted and checked. Candidates should use a sharp pencil when plotting points and use a transparent 30 cm ruler when drawing the line of best fit and the worst acceptable line; care is also needed when reading information from the graph.
- The numerical answers towards the end of **Question 2** require candidates to show all their working, particularly when determining uncertainties. A full understanding of significant figures is required.
- The practical skills required for this paper should be developed and practised over a period of time with a 'hands on' approach.

General comments

The vast majority of candidates completed the paper in the time available. Most scripts were clearly written. Writing in black or dark blue ink makes the scripts easier to read.

In **Question 1**, candidates did not always describe the method in the necessary detail. Circuit diagrams could also be improved. In some answers there was a lot of irrelevant writing; it is advisable that candidates should think carefully about the experiment following the points given on the question paper and to imagine how they would perform the experiment in the laboratory.

In **Question 2**, graphs were well drawn with points and error bars easily identifiable. Candidates should be advised that, to gain the highest marks, the presentation of mathematical working requires a clear statement of the equation used and clear substitution of numbers, leading to the correct answer. Furthermore, the working has to be logical and readable.

It is clear that the stronger candidates have experienced a practical course where the skills required for this paper are developed and practised over a period of time with a 'hands on' approach. To assist Centres, Cambridge has produced practical support booklets which are available from the Teacher Support Site.

Comments on specific questions

Question 1

Candidates were required to investigate the characteristics of different light-emitting diodes (LEDs). They were to investigate the relationship between the minimum potential difference V across an LED and the wavelength λ of the light emitted by the LED for several different LEDs.

Many candidates were not awarded credit for identifying the dependent and independent variables. They often correctly chose the variables but interchanged them, i.e. V was selected as the independent variable. Most of these candidates received partial credit for stating that they would measure the p.d. across the LED. On this particular question there was no constant in the given relationship though many candidates stated current was to be kept constant.

Four marks are available for the methods of data collection. Credit was awarded for a correct, workable electric circuit. Candidates should be encouraged to use correct circuit symbols. Common errors included voltmeters connected in series or not connected across the LED, or no d.c. source shown. A significant number of candidates correctly placed a variable resistor in the circuit or labelled the power source as variable. Candidates should check the polarity: a mark for additional detail was available for showing the correct polarity of the power supply so that the diode was forward biased.

Many candidates thought that a light detector connected to a cathode-ray oscilloscope can measure the frequency (wavelength) of light, but this was not awarded credit. Stronger candidates selected a diffraction grating or Young's slits, gave good explanations and gained an additional detail mark for the correct equation to determine the wavelength. When quoting equations, candidates should define all the symbols used and should make the quantity being determined the subject of the equation.

The final mark for data collection was for the practical method of obtaining the minimum p.d. across the LED when it just lights. Many candidates did not state how they would use the circuit in order to measure the p.d. across the diode. It was expected that the p.d. would be increased slowly by the variable power source or by changing the resistance of the variable resistor until the LED just emits light. Candidates often described measuring the p.d. with a voltmeter but tended not to explain how the exact point when the LED just lights was achieved.

There are now three marks available for the analysis of data. The majority of candidates scored the first mark for identifying a graph to plot, though a few candidates did not convert the quantities to logarithms. Both logarithms to the base ten and natural logarithms were accepted. The determination of the value of n equal to the gradient was often given by candidates. To be awarded credit for determining constants, candidates must give the constant as the subject of the equation: $\log k = y$-intercept was not sufficient. Many candidates stated that the y-intercept would be zero; this would be true only if $k = 1$.

The additional detail section had a maximum of six marks that could be awarded. The marking points allowed candidates to broaden their answers and most obtained several of these marks. Candidates should be encouraged to write their plans including appropriate detail; often candidates' answers suggested that they did not have sufficient practical experience. Vague responses were not credited. Those candidates who have followed a 'hands on' practical course are generally much better placed to gain credit for additional detail. It is essential that candidates give detail relevant to the experiment in question rather than general 'textbook' rules for working in a laboratory.

Candidates should be made aware that the bland statement of "the experiment is repeated and an average is taken" is not awarded credit. More detail is required, such as "for the same wavelength, the experiment is repeated and V is recorded again and the average value of V is then determined".

Question 2

The question required candidates to analyse data given for how the extension e of a loaded wire depends on the diameter d of the wire.

(a) This question was generally answered well.

(b) Nearly all candidates were awarded credit for the column heading. The common mistake in the $1/d^2$ column was stating the first value to four significant figures. Since the raw data were given to two significant figures, it was expected that $1/d^2$ would be given to two or three significant figures. The majority of candidates calculated the absolute uncertainty correctly; a common error was not doubling the percentage uncertainty for d^2.

(c) (i) The majority of candidates scored full credit for the plotting of the data points with the corresponding error bars. Common reasons for loss of credit were vertical error bars and drawing large 'blobs' for the plotted points.

(ii) Both the line of best fit and worst acceptable line were generally drawn well. Candidates should clearly indicate the lines drawn.

(iii) Most candidates clearly demonstrated the points that they used to calculate the gradient. Candidates are improving in their ability to select points that are on the line rather than quoting values from the table, and most could choose a sensibly-sized triangle. A significant number of candidates had a power of ten error having not used the data from the axes correctly.

(d) (i) It is vital that the working for the answer is clearly shown. The equation should be quoted followed by correct substitution of numerical values, one of which must be the value of the gradient calculated in **(c)(iii)**. Many candidates did not give a correct unit, and several candidates did not give any unit. There were many variations such as $N\,m^{-1}$. Candidates should be encouraged to determine the correct unit from the equation.

(ii) There was good recognition that the percentage uncertainty in *E* was the sum of the percentage uncertainties of the three necessary components in the equation. Those candidates attempting to use a 'maximum/minimum' method tended to make mistakes by not clearly showing where their data has originated or by using incorrect combinations of maximum and minimum values.

(e) A number of candidates correctly realised that *e* was equal to the gradient/d^2 and determined the absolute uncertainty correctly. The calculated value of *e* needed to be quoted to two or three significant figures and be given with the correct power of ten, and its value needed to fall within a given range. Clear, logical working was required, and candidates who could not demonstrate their understanding by showing the method were not awarded credit. A large proportion of candidates were unable to give a correct solution to finding the absolute uncertainty in *e*. It was expected that appropriate equations would be used with substitution of data.