PHYSICS

Paper 9702/11
Multiple Choice

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

General Comments

The time constraint of one hour does make the paper a challenge: it demands quick and accurate working by candidates. The average time of 90 seconds per answer is made possible by having many questions that can be answered after a quick (but careful) read through the question.

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.

The candidates found **Questions 1**, **18** and **27** relatively easy. Questions **5**, **11**, **19**, **33** and **35** were difficult.

Comments on Specific Questions

Question 3

It should be possible for candidates with a good understanding of the size of physical quantities to answer this question relatively quickly. The GHz frequency range is orders of magnitude too large for sound.

Question 5

The measurement first should be corrected for the zero error, which gives (8.4 ± 0.2) mm for the four rods. This can then be divided by four to obtain (2.10 ± 0.05) mm. Many candidates chose **C**, perhaps thinking that the uncertainty of 0.1 mm applies throughout. The purpose of measuring four rods rather than one rod is to reduce the effect of random error.

Question 6

A very common answer was **A**. This shows a finite value of I at $d = 0$ so it cannot represent inverse-square proportionality.

Question 7

Candidates found this question difficult and each answer needs to be considered carefully in turn. The graph showing $u = 0$ cannot be correct because the marble will always have a non-zero speed as it passes light gate 1.

Question 11

The change in momentum is given by the impulse, i.e. average force × time or the area under the graph. Dividing by the mass then gives the change in speed.

Question 14

The blocks fall freely and they exert no force on each other. Many candidates chose **B**.

Question 19

The pressure of the trapped air plus the pressure of the mercury column of height h must equal the total pressure supplied by the piston. Therefore $P_{air} + \rho gh = P_{at} + mg/A$ where m is the mass of the piston and A is its area. Solving this gives h = 110 cm.

Question 30

The electric field strength depends on the potential difference between the plates, so the two field strengths are E_X (= [500 – 200] / 2.0) = 150 V cm^{-1} and E_Y = 200 V cm^{-1}. Answer **C** was popular and incorrectly obtained by using 500 V as the potential difference between the upper and middle plates.

Question 33

The energy of each pulse is (220 V × 15 A × 2.0 × 10^{-3} s =) 6.6 J. There are 200 pulses per second, so the power output is (6.6 J × 200 s^{-1} =) 1.3 kW.

Question 35

If the full potential difference of the supply is measured across the fuse, then the fuse must have melted (answer **A**). Normally there would be no potential difference across a fuse, so all of the other three situations would give a voltmeter reading of zero.

PHYSICS

Paper 9702/12
Multiple Choice

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

General Comments

The time constraint of one hour does make the paper a challenge: it demands quick and accurate working by candidates. The average time of 90 seconds per answer is made possible by having many questions that can be answered after a quick (but careful) read through the question.

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.

Questions 1, **3**, **4** and **33** were found to be relatively straightforward by candidates. **Questions 7** and **25** were difficult.

Comments on Specific Questions

Question 7

The important point of physics here is that, if air resistance is ignored, the acceleration is always g in a downward direction whether the ball is rising, stationary or falling. Many candidates chose answers **A** and **D** suggesting that g changed direction and was zero when the ball stopped.

Question 11

The most popular answer was **B**. This cannot be correct: if the force that X exerts on Y is equal to F, then X does not accelerate. For X to accelerate, there must be a resultant force on X, and therefore the force that Y exerts on X must be less than F. The force exerted by X on Y is equal by Newton's third law, and therefore also less than F, so **C** is correct.

Question 12

Before the thread is burned, the downward force on the larger mass is 3.0 N (2.0 N weight + 1.0 N weight of the smaller mass). The spring exerts an equal upward force. When the smaller mass is released, there is an instantaneous resultant force of 1.0 N upwards on the 0.20 kg mass, giving an acceleration of 5.0 m s^{-2} (answer **A**).

Question 17

Answer **A** was popular, but work is done on the atmosphere to push the air near the tyre out of the way.

Question 25

A common wrong answer was **B**. Surface waves on water demonstrate interference and diffraction easily but do not easily show polarisation. The movement of a wire can be horizontal or vertical (or a combination of the two).

Question 28

The wave in this minimum length must have a node at the bottom and an antinode at the top, i.e. the length of the tube is a quarter of a wavelength. Longer tubes supporting a stationary wave must have nodes and antinodes in the patterns NANA (75 cm), NANANA (125 cm), etc. A relatively large number of candidates chose **B**.

Question 35

The power dissipated in the load resistor is maximum when the load resistance equals the internal resistance of the supply.

Question 37

This question required logical thought and there are several possible approaches. The current and resistance are given in the middle branch of the circuit, which allow the potential difference of (1.2 × 80 =) 96 V to be calculated. The 'lost volts' of the power supply must therefore be (120 – 96 =) 24 V. The current in the supply is (1.2 + 0.4 =) 1.6 A. The internal resistance is therefore (24 / 1.6 =) 15 Ω.

Question 38

Candidates found this question difficult. In answering this type of question, candidates should be encouraged to draw a circuit diagram. Once a diagram has been drawn, it is relatively straightforward to see that **D** is a series circuit in which the two meters must have the same currents.

PHYSICS

Paper 9702/13
Multiple Choice

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

General Comments

The time constraint of one hour does make the paper a challenge: it demands quick and accurate working by candidates. The average time of 90 seconds per answer is made possible by having many questions that can be answered after a quick (but careful) read through the question.

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.

Questions 1, **2**, **20**, **23** were the easiest questions on the paper. Candidates found **Questions 19**, **34**, **36** and **37** difficult.

Comments on Specific Questions

Question 4

A common incorrect answer was **C**, which is the opposite of the correct answer. Candidates should be encouraged to learn the meaning of these terms carefully.

Question 8

The area under a speed-time graph gives the change in distance, but the two animals here did not start at the same position. Many weaker candidates forgot the initial separation of 100 m, and this led them to choose **D**.

Question 10

The key point that candidates needed to realise was that the graphs show only the motion between the bounces. The horizontal component of the velocity is constant, so **C** is correct. Some candidates chose **D**, which would have been the correct shape for the vertical component.

Question 11

This question was found to be relatively difficult. A common mistake was to choose **D**, which is the upward force F divided by the mass m. The upward force is not the resultant force because the rocket has weight. The correct equation is $F - mg = ma$ and solving this gives **C**.

Question 19

This question can be answered by determining the pressure at the boundary between the oil and the water. The pressures exerted by the oil and by the water at this boundary must be equal. The pressure of the oil is $30.0\rho_{\text{oil}}g$ and the pressure of the water is $(30.0 - x)\rho_{\text{water}}g$. Solving this gives $x = 4.5$ cm.

Question 34

Careful working is needed to answer this question. The resistances of the lamps can be determined from the ratings and the question states that these resistances are constant. Lamp P has a resistance of ($250^2 / 50$ =) 1250 Ω and lamp Q has a resistance of 312.5 Ω. They are connected in series so they have the same current, and therefore power $\propto$ resistance. The power in lamp P is four times the power in lamp Q.

Question 35

A popular incorrect answer was **B** but this would allow the clock to operate the cooling system when the thermostat switch is open (i.e. the house is already cold). The clock and thermostat switches must be in series for normal operation of the system.

Question 36

When the circuit is working correctly, there is a p.d. of 110 V between S– and C1. Faults **B**, **C** and **D** would each cause the p.d. between S– and C1 to fall to zero.

Question 37

Candidates found this question difficult and it requires careful working. The currents in the three 'horizontal' resistors are 8 A, 3 A and 1 A; the corresponding potential differences are 8 V, 3 V and 1 V. The currents in the three 'vertical' resistors are 5 A, 2 A and 1 A; the corresponding potential differences are 5 V, 2 V and 1 V. The total current in the supply is 8 A and the potential difference V is 13 V.

PHYSICS

Paper 9702/21
AS Structured Questions

Key Messages

- There are a number of questions on the paper that require general recall. Candidates should review the learning objectives and ensure they are well prepared to give correct answers to this type of question.
- Candidates should be reminded that, where a question asks for a statement and an explanation, the explanation is essential to receive full credit. Credit is frequently lost when candidates do not show a clear link between the stages in an argument.
- Candidates should choose their wording carefully, especially when giving a definition or describing a situation. Often answers are made unclear through the omission of certain key words and inappropriate use of everyday language.
- It is important that numerical answers are fully worked out and presented as decimals and not fractions. Candidates should be reminded that full credit is not awarded for answers inappropriately given as fractions.

General Comments

The majority of candidates were able to give the basic formulae required for the calculations on this paper. Many candidates found it difficult to complete the solutions to many of the applications of the basic theory. Examples of such applications were in **Questions 1**, **2**, **3**, **4** and **6**. There were general omissions in basic theory and this was particularly noticeable in **Question 1** (uncertainties), **Question 2** (the use of the c.r.o.), **Question 5** (stationary waves) and **Question 7** (the properties of α- and β-particles).

Comments on Specific Questions

Question 1

(a) The majority of candidates gave correct responses for this straightforward first question. A significant number were unable to give two base quantities.

(b) (i) 1. Some candidates were able to start from the expression for the Young modulus and derive the required SI base units. In 'show that' questions, the full working must be shown. Candidates were expected to show that strain had no units rather than ignore it from the expression for the Young modulus.

2. Many candidates were able to determine the correct base units of *K*. There were many answers that had errors due to incorrect rearrangement of the given expression or in dealing with the square root.

(ii) Candidates found it difficult to determine the total percentage uncertainty and hence the actual uncertainty in the value of *E*. The majority of candidates did not add the given percentage uncertainties for the terms in the expression for *E*. The correct method of calculating the total uncertainty by including the power of each term was used by a very small number of candidates.

Question 2

(a) Many candidates were unable to use the signal shown on the figure to determine the time period of the wave. There were many candidates who tried to determine the wavelength of the microwaves directly from the figure. A significant number did not realise that the speed of microwaves is the same as the speed of light.

(b) There were very few correct answers. The link between the ratio of the wavelengths and the ratio of the time-base settings was used by a very small minority.

Question 3

(a) A small number of candidates were able to explain why the work done against a gravitational field does not depend on the path taken.

(b) (i) The majority of candidates were able to read the time for the ball to reach maximum height from the graph and go on to determine the initial vertical velocity.

(ii) The majority of candidates drew a straight line. Some candidates lost credit by not drawing the line carefully to the given final distance at the time of 3.0 s.

(iii) Most candidates were able to state the formulae for potential and kinetic energy. Many of the candidates were then unable to determine the velocity of the ball at maximum height from the information in the question. A significant number stated that the velocity at maximum height is zero.

(iv) There were a large number of misconceptions given in the answers. Many of the candidates stated that the ball would reach the same height and therefore take a longer time due to the air resistance. The combined effect of the gravitational force and air resistance reducing the initial velocity to zero over a shorter time was given by a very small number of candidates.

Question 4

(a) The majority of candidates were able to start with the correct expression for density. The majority of errors were made converting the units for the height and area into m and m^2 respectively.

(b) The majority of candidates were able to start with the correct expression for pressure. Many candidates were unable to determine the force acting normally to the surface using the correct component of the weight.

(c) The majority of candidates were able to quote a general expression relating force and acceleration. Fewer candidates were able to state the resultant force acting on the cylinder as the weight component down the slope minus the force due to friction.

Question 5

(a) Candidates found it difficult to describe the differences between progressive waves and stationary waves. Candidates would benefit from learning these properties of waves thoroughly.

(b) (i) Candidates were generally unable to translate the information given into a recognisable diagram of a stationary wave, and should be encouraged to practise answering more questions of this type. The correct maximum amplitude was not drawn by the majority of candidates.

(ii) The phase difference between different sections of a stationary wave was not known by the majority of candidates.

(iii) Most candidates were unable to describe the motion of a particle vibrating as part of a stationary wave.

Question 6

(a) A very small minority were able to state the definition of electromotive force in terms of the required energy transformations.

(b) (i) The majority of candidates were able to calculate the current in the circuit by including all the resistances in the circuit. A small number incorrectly ignored the internal resistance of the battery.

(ii) The terminal potential difference was correctly calculated by only a small number of candidates. A significant number calculated the potential difference across the internal resistance and hence gave the 'lost volts' as their answer instead of the terminal potential difference.

(c) (i) Many candidates were unable to determine the resistance of the wire Z and could then make little progress with this question. The knowledge and understanding of the proportional relationship between resistance and length and the inverse proportionality between resistance and cross-sectional area are a requirement of the learning objectives.

(ii) The majority of candidates were unable to describe the link between the reduction in the resistance in the circuit and the effect on the current and hence the 'lost volts' and terminal potential difference.

(d) The majority of candidates were able to start with the correct expression for electrical power. The correct terminal potential difference and circuit current for the two circuits were used by a very small minority of candidates.

Question 7

(a) (i) A small number of candidates were able to show the path of the α-particle curving towards the negative plate.

(ii) Very few candidates realised that α-particles have a limited range in air due to ionisation.

(iii) The majority of candidates stated the correct expression for the electric field. Some errors were made by not converting the separation from mm to m and not giving the potential difference in MV.

(b) The question asked for the properties of the α- and β-particles that produced different deflections. Many candidates stated only the differences in the deflections without any reference to the property involved.

(c) The changes to *Z* and *A* when α- or β-particles are emitted were known by a small minority of candidates.

PHYSICS

Paper 9702/22
AS Structured Questions

Key Messages

- There are a number of questions on the paper that require general recall. Candidates should review the learning objectives and ensure they are well prepared to give correct answers to this type of question.
- Candidates should be reminded that, where a question asks for a statement and an explanation, the explanation is essential to receive full credit. Credit is frequently lost when candidates do not show a clear link between the stages in an argument.
- Candidates should choose their wording carefully, especially when giving a definition or describing a situation. Often answers are made unclear through the omission of certain key words and inappropriate use of everyday language.
- It is important that numerical answers are fully worked out and presented as decimals and not fractions. Candidates should be reminded that full credit is not awarded for answers inappropriately given as fractions.

General Comments

There were parts of some questions that were testing, allowing well-prepared candidates to show their understanding of the relevant concepts. Other parts of questions were straightforward so that weaker candidates would not be discouraged.

It is important that candidates understand the mathematical requirements of the syllabus. Mathematical approaches to **Question 1(d)(ii)** (rather than scale drawing) often resulted in incorrect answers. Many candidates were not able to calculate the volume of a sphere in **Question 8(b)**.

Candidates generally performed better on the questions involving calculations. Answers that required some discussion or explanation were often not as well answered.

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

Comments on Specific Questions

Question 1

(a) A majority of candidates calculated a correct value for the wavelength in metres. A significant number found the conversion to picometres difficult. A common mistake was to multiply by 10^{-12} rather than divide. Some candidates did not realise that X-rays travel at the speed of light and that this value was available on the data page.

(b) The majority of candidates obtained the correct answer in seconds. The conversion to Gs again caused difficulties. There were some candidates who were unable to use the correct value for the speed of light. The speed of sound was the most common incorrect speed used.

(c) The majority of answers were correct. The most common omission was power.

(d) (i) Many candidates were unable to draw a line to represent the resultant direction of the boat, and would benefit from further practice of this type of question. A small minority of candidates gave no response.

(ii) The most successful method of obtaining the magnitude of the velocity was by scale drawing. The mathematical routes often included a mistake. Candidates who used the cosine rule often used an angle of 120° rather than 60° or the negative sign was omitted. Where the components of the velocities in the vertical and horizontal directions were calculated, the horizontal component was often incorrect. Candidates using the mathematical approach would benefit from drawing a sketch of the vectors in their approximate magnitude and direction in order to get an idea of the possible value for the resultant.

Question 2

(a) (i) The majority of candidates were able to select the appropriate equation. The substitution of the data by many candidates suggested that the significance of the symbols and the method of treating a deceleration were not as well known. A negative time was often the result of incorrect substitution. Candidates should reconsider their calculation rather than simply omitting the negative sign in this situation.

(ii) Many candidates obtained the correct answer. A significant number used speed = distance / time and ignored the information given that there is constant acceleration.

(b) Many candidates found it difficult to use the given data and select the appropriate equation of constant acceleration. Many of the candidates were able to determine the distance travelled down the slope. Only the stronger candidates were able to use this distance and the information given to answer the question successfully.

(c) There were many answers that gave the first part of the graph correctly to a time of 1.2 s where the velocity was zero. The line was then often continued at a different gradient and did not end at the given final velocity. There were many answers that showed a 'V'-shaped line that was confined to the positive values of velocity. A significant number of candidates gave no response to this question. Candidates should be reminded that constant acceleration results in a constant gradient for a velocity-time graph throughout the motion.

(d) A majority of candidates obtained the correct answer. Common mistakes were in converting the units of mass, squaring the difference in the velocities and not squaring the velocities after giving the correct equation for kinetic energy.

Question 3

(a) (i) The majority of candidates gave the correct expression for the spring constant. The most common mistakes were not converting the units of compression into metres or giving the gradient as the value for *k*. Some candidates chose unsuitable points on the graph which gave them an answer outside the accepted range.

(ii) There were many good answers using the spring constant or the area under the line. The use of force × distance was common in many incorrect answers. Candidates should be made aware that this equation is inappropriate because the force is not constant as the spring is compressed.

(b) (i) The answers were generally not given in sufficient detail for this level. The change from kinetic energy to elastic energy was commonly described without reference to the objects involved. The energy was then often considered to be converted to heat and/or sound without reference to the reduced kinetic energy of the trolley as it rebounded.

(ii) The correct equation for momentum was quoted by the majority of candidates. A significant number did not take into account the vector nature of momentum and subtracted the final and initial momentum values rather than adding them.

Question 4

(a) A common omission was the reference to the distance being 'perpendicular' or between the line of action of the force and a turning point or pivot. Candidates should be reminded that the definition is incomplete without this.

(b) (i) Many candidates found it difficult to determine the perpendicular distance from the point of action of the force and the point A. Some candidates were able to state at least one of the moments correctly.

(ii) A minority of candidates were able to calculate the vertical component of tension.

(iii) A small minority were able to explain that a vertical upward force must be present where the beam makes contact with the wall. Many answers referred to a horizontal force. This answer did not relate to the question that was about the vertical forces of load and weight.

Question 5

(a) (i) Many candidates calculated the correct answer. A small number incorrectly used only one of the resistors in the branch or stated that the current divided equally into the two branches.

(ii) The majority of candidates calculated the correct resistance.

(iii) The majority of candidates were able to give an expression for power. The successful candidates usually used the expression $P = I^2R$. Those candidates who used an expression involving V tended to use the potential difference of the supply rather than the potential difference across the specific resistor. There were many answers given as improper fractions. Candidates should be reminded that they must calculate answers fully and should not provide answers that are fractions.

(b) (i) The correct answer was obtained only by the strongest candidates. There were many answers with no response. Many candidates would benefit from further practice of methods to determine the potential at particular points in a circuit or the potential difference across components in a circuit.

(ii) There were very few correct answers. A large number of candidates gave answers without any explanation or stated only that the potential increases when the resistance increases because V is proportional to R.

Question 6

(a) Candidates found the explanation difficult. A small minority correctly linked the 'lost volts' due to internal resistance of the battery with the terminal p.d. being below 12 V.

(b) (i) The majority considered an explanation involving incorrect physics, stating that the current in the lamps would be less because the currents now split at the junction. This is a fundamental misconception. A very small number correctly suggested that the 'lost volts' would be greater as more current would be supplied by the battery. This would result in the terminal p.d. being reduced and the power output of each lamp to be less.

(ii) Candidates found it difficult to apply the I-V characteristics of a lamp to this circuit. The current was often stated as being less through the lamps, but the link between smaller current and less resistance was often omitted. Many candidates incorrectly applied Ohm's law to the lamps.

Question 7

(a) Both parts of this question were generally well answered.

(b) (i) This was well answered by the more able candidates. There were some incorrect explanations that referred to the need for a reflector for stationary waves, or stated that the waves were stationary due to the fact that interference was taking place.

(ii) This was generally well answered by the more able candidates. There were many answers that referred to the need for the same frequency or amplitude but missed the crucial point of constant phase difference.

(c) (i) There were a large number of blank responses, and many of the answers did not answer the question. There were a few answers that gave the correct path difference and suggested that constructive interference would occur but these answers did not always go on to explain the effect on the displacement of the water. It is important for candidates to read the question carefully.

(ii) There were a large number of blank responses. The answers were generally similar to those in **(c)(i)**. Some candidates gave a general statement for destructive interference without applying it to this specific question.

Question 8

(a) The majority of candidates had the correct ideas for the results of the α-particle scattering experiment. The terms used to explain the proportion that would go straight through compared to those that were deflected by angles greater than 90° were often not specific enough. The terms 'some', 'a lot' or 'many' are too vague. The conclusion that referred to the atom being mostly empty space was stated by many of the candidates. Very few referred to mass and charge being concentrated in the nucleus. There were a significant number of blank responses and answers that listed the properties of α-particles. This suggested that the experiment was not known by a significant number of candidates.

(b) The majority of candidates were able to start this calculation by quoting the correct expression for density. Candidates found it difficult to progress further as they did not realise that the mass of the atom and the nucleus were almost identical. There were many incorrect variations used to calculate the volume of a sphere.

PHYSICS

Paper 9702/23
AS Structured Questions

Key Messages

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- Candidates should choose their wording carefully, especially when giving a definition or describing a situation. Often answers are made unclear through the omission of certain key words and inappropriate use of everyday language.
- It is important that numerical answers are fully worked out and presented as decimals and not fractions. Candidates should be reminded that full credit is not awarded for answers inappropriately given as fractions.

General Comments

There were parts of some questions that were testing, allowing well-prepared candidates to show their understanding of the relevant concepts. Other parts of questions were straightforward so that weaker candidates would not be discouraged.

Candidates generally performed better on the questions involving calculations. Answers that required some discussion or explanation were often not as well answered.

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

Comments on Specific Questions

Question 1

(a) Credit for this part was awarded for clear explanation. Most candidates commenced by giving appropriate units for power or energy. In some cases the subsequent working and cancellations to give the result were unclear. Candidates should be reminded that it is especially important for the working to be clear in this type of question as credit is not awarded for the final answer.

(b) (i) Having written down all the units for the various components, the subsequent working was not always clear. It was common to find that the conclusion reached was ‘1 = 1’ or ‘0 = 0’.

(ii) In most scripts, the calculation of the intensity in $\mathrm{W\,m^{-2}}$ was completed successfully. Candidates found it more difficult to convert to $\mathrm{pW\,m^{-2}}$, and many stated the answer without conversion.

Question 2

(a) (i) Candidates found it difficult to focus their answer on the specific situation given. In very few answers was a reference made to the signal generator being connected to both loudspeakers. Often an attempt was made to explain generally what is meant by coherent waves.

(ii) In each part, it was expected that the phase angle or path difference would be quoted and then the effect on the resultant displacement stated. There were few fully correct answers. Many candidates stated general conditions for phase difference. Others made reference to path difference but then confused this with phase angle.

(b) There were some very carefully drawn curves but many answers could be credited only for a correct period or a correct amplitude.

Question 3

(a) (i) 1. This calculation caused very few problems. Candidates should be advised always to use the given data, unless told otherwise. The approximation $g = 10\,\mathrm{m\,s^{-2}}$ should be avoided.

2. It was expected that candidates would use ideas related to conservation of energy and hence equate the maximum kinetic energy to the change in gravitational potential energy. In practice, most correctly calculated the final speed and then used the expression $E_K = ½mv^2$.

(ii) Very few answers included both a statement and some explanation. The most common answer was a statement without explanation to the effect that the velocity increases with time. It was expected that a reference would be made to velocity being proportional to time elapsed because the acceleration is constant.

(iii) In many scripts, the calculation already carried out successfully in **(a)(i) part 2** was repeated here.

(b) (i) Generally, it was stated that the air resistance would increase as the velocity increases, giving rise to a reducing acceleration. Often there was no reference to the resultant force or there was a statement that the final acceleration would be zero.

(ii) Candidates found this difficult. The most common mistake was to assume that the force due to air resistance was the accelerating force.

(iii) A small number of candidates made a correct reference to the fact that, at a speed of $60\,\mathrm{m\,s^{-1}}$, the air resistance is less than the weight. Most attempted an unsuccessful explanation based on the fact that the graph extends beyond $60\,\mathrm{m\,s^{-1}}$.

Question 4

(a) (i) Many candidates correctly considered the component of the force and used this correctly to determine the reaction force.

(ii) As in **(a)(i)**, a correct solution was seen in most scripts. The most common mistake was not to use the horizontal component of the force.

(b) (i) This question concerned work done, but very few answers involved energy. In many answers there was some discussion of forces in equilibrium.

(ii) Candidates should be encouraged to use terms such as ‘equal and opposite’, rather than ‘cancels out’ or ‘balanced’. The use of imprecise terminology frequently meant that credit could not be given.

Question 5

(a) (i) A very common error was to assume that resistance is the gradient of a voltage/current graph. This is a common misconception and candidates would benefit from further emphasis on the definition of resistance. Those who did recognise resistance as the ratio V/I frequently wrote that zero current would be associated with zero resistance.

(ii) This was completed successfully in most scripts.

(b) (i) Again, there were very few problems with this calculation.

(ii) A common error was to give the answer for the total resistance of R_1 and the diode.

(iii) With few exceptions, candidates did give a correct expression for power. Many candidates found it difficult to substitute appropriate values of current and resistance into the equations. It may be helpful for candidates to write the currents on the circuit diagram to avoid confusing the currents in different branches of the circuit.

Question 6

(a) This was answered well in many scripts. A common problem was to omit to state that the reflected wave interferes/overlaps with the incident wave.

(b) (i) The most common answers were 0.68 m and 0.34 m. Only a small number of candidates determined correct values.

(ii) On those diagrams where more than one node and one antinode were labelled, intermediate nodes and antinodes were sometimes not equally spaced. Frequently, a node or an antinode was shown at the centre of the tube.

Question 7

(a) In most scripts, a correct expression was quoted for stress in terms of force and area. The most common problems were associated with either taking 15^2 as the area in m^2 or with powers-of-ten when converting mm^2 to m^2. Candidates may benefit from further practice at unit conversions.

(b) Density involves mass and there was some confusion as to the use of *g*. Some weaker candidates incorrectly attempted to base their answer on the expression $R = \rho L/A$, perhaps because it involves length and area.

Question 8

(a) Many suggestions were made. Candidates should avoid referring to mass and energy separately in this type of question; 'mass-energy' is the preferred term for the conserved quantity. Candidates should be advised as to the correct use of terms such as 'proton number', 'number of protons', 'nucleon number' and 'number of neutrons'.

(b) (i) This part was completed successfully by a significant number of candidates.

(ii) There were few correct solutions. In general, candidates did not use the expression given in **(b)(i)**. A common mistake was to calculate the speed of the α-particle and then to assume that this would be the speed of the thorium nucleus.

PHYSICS

Paper 9702/31
Advanced Practical Skills 1

Key Messages

- 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. The scale should be chosen so that it is easy to use, and should not be based on multiples of 3, 7 etc.

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

- Well-prepared candidates are able to give many valid limitations and solutions for the last part of **Question 2**. Many weaker and less confident candidates score little or no credit. It is recommended that when learners have carried out an experiment in class (or been shown a demonstration) they address as a group the real problems and solutions that may arise, perhaps by first considering each measurement taken or going through the procedure in order. This can be done at the end of a lesson as a recap and set as homework to consolidate learning.

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. 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. It is essential that a full set of specimen results from the Supervisor are also included with the candidates’ scripts.

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

Candidates did not seem to be short of time. The candidates 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 effect of air resistance on the motion of a circular card.

Successful collection of data

(a) (iv) The majority of candidates correctly stated a value of *d* in range with a unit. Some candidates omitted the unit.

(c) (ii) Most candidates stated a repeated value of *N*.

(e) Most candidates were able to collect six sets of values of *d* and *N* without any assistance from the Supervisor.

Range and distribution of values

(e) Many candidates did not extend their range of *d* values used to include $d < 9.5$ cm. Candidates should be encouraged to make full use of the apparatus available. In this case, many candidates could have cut much smaller circles from the card.

Quality of data

(f) (i) Most candidates were awarded credit for the quality of their data. Some of those who were not had calculated $1/d$ or $\sqrt{N}$ incorrectly.

Table

(e) 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 were unsure of the units for $1/d$ or omitted the unit and/or separating mark.

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

Most candidates calculated values for $\sqrt{N}$ correctly. A few rounded their answers incorrectly.

Many candidates recorded their calculated values for $1/d$ to an appropriate number of significant figures.

Graph

(f) (i) The size and scale of the graph axes chosen was generally good so that the plotted points occupied greater than half the graph grid and the scale was easy to read. A minority of candidates drew awkward scales on both axes (e.g. multiples of 3 were 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 of $\sqrt{N}$ versus $1/d$ correctly. A few candidates plotted the wrong graph (e.g. *d* versus $\sqrt{N}$ or $1/d$ versus *N*). 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 an anomalous point is ignored in assessing the straight line of best fit, the point should be labelled clearly (e.g. by circling it). In some cases, candidates did not ignore the identified anomalous plot in judging where to put the line of best fit through the points.

Most candidates plotted their points on the graph grid with great care. Others needed to draw the plotted points so that the diameters of the points were equal to, or less than, half a small square (a small pencil cross is recommended). Some candidates can improve by plotting the points more accurately and by ensuring they use a sharp pencil and a straight ruler. The graphs of some candidates were difficult to see because the points were faint or the points had been rubbed out and redrawn many times.

(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. Some lines were forced so that the intercept could be easily read off the *y*-axis. 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. Candidates should be encouraged to use a clear 30 cm ruler when establishing the position of their line of best fit.

Interpretation of graph

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

Some candidates were able to correctly read off the *y*-intercept at $x = 0$ directly from the graph. Many candidates read off the *y*-intercept when there was a false origin.

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

Drawing conclusions

(g) Most candidates recognised that *A* was equal to the value of the gradient and *B* was equal to the intercept. A small number of 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*.

Some candidates recorded the correct units for *A* (m) and no units for *B*. Other candidates omitted units for *A* or added a unit to *B*.

Question 2

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

Successful collection of data

(a) (ii) Most candidates recorded a value for *x* in range and to the nearest millimetre. Some candidates incorrectly stated values to the nearest centimetre when the distances can be measured to the nearest millimetre.

(c) (ii) Many candidates recorded repeat values of *R* with a unit. Some candidates omitted the unit.

(d) Most candidates recorded second values for *x* and *R*.

Quality of data

(d) Most candidates correctly recorded a smaller value for *R* when the nail is through Q.

Display of calculation and reasoning

(b) (i) Most candidates correctly calculated *C* with consistent units. Some candidates used one unit of length in their calculation and then either stated inconsistent units or did not give any units in the answer.

(ii) Many candidates justified the significant figures they had given for the value of *C* by giving reference to the number of significant figures used their *x* and *h* readings. Some candidates gave reference to 'raw' readings without qualifying what the raw readings were or related their significant figures chosen to just *x*.

(e) (i) Many candidates were able to calculate *k* for the two sets of data, showing their working clearly. A few candidates rearranged the equation to calculate *k* incorrectly.

Drawing conclusions

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

Estimating uncertainties

(c) (iii) Most candidates were familiar with the equation for calculating percentage uncertainty, though some candidates made too small an estimate of the absolute uncertainty in the value of *R*, typically 1–2 mm, to be valid for this particular experiment. Some candidates successfully repeated their readings and correctly gave the uncertainty in *R* as half the range.

Evaluation

(f) Many candidates recognised that two sets of data were insufficient to draw a valid conclusion. Many candidates identified that the ball does not move along a straight path from the wooden cube and offered a solution of putting a groove in the cube. Another valid difficulty stated by candidates was identifying *R* because the marble skids and leaves an elongated hole.

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 'systematic error', 'parallax error', 'air conditioning', 'faulty apparatus' or 'use an assistant' are not given credit. Some improvements relied heavily on robotic devices and these often did not gain credit e.g. use a 'robotic arm' or a 'mechanical arm'. Other devices without clarification also could not be awarded credit, such as the use of a video without reference to a scale (in this case) or the use of a stand and clamp without reference to the function of the suggested apparatus in improving the experiment.

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. Candidates should write about four different problems (perhaps relating to the different measurements undertaken) stating how these difficulties impact on the experiment. Candidates should then be encouraged to think of associated solutions that address these problems, and should not state four solutions to the same problem.

PHYSICS

Paper 9702/33
Advanced Practical Skills 1

Key Messages

- 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. The scale should be chosen so that it is easy to use, and should not be based on multiples of 3, 7 etc.

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

- Well-prepared candidates are able to give many valid limitations and solutions for the last part of **Question 2**. Many weaker and less confident candidates score little or no credit. It is recommended that when learners have carried out an experiment in class (or been shown a demonstration) they address as a group the real problems and solutions that may arise, perhaps by first considering each measurement taken or going through the procedure in order. This can be done at the end of a lesson as a recap and set as homework to consolidate learning.

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. 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. It is essential that a full set of specimen results from the Supervisor are also included with the candidates' scripts.

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

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

Comments on Specific Questions

Question 1

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

Successful collection of data

(b) (i) The majority of candidates correctly stated a value of L to the nearest millimetre. Some candidates omitted the units or stated the value to the nearest centimetre. A few candidates unrealistically claimed they could read their values to the nearest 0.1 mm.

(c) With the added mass, most candidates correctly found that their new value of h was larger than that found in **(b)(ii)** and stated a reasonable value for angle θ.

(d) (ii) Most candidates were able to collect six sets of values of m, h and θ without any assistance from the Supervisor.

Range and distribution of values

(d) (ii) Many candidates did not extend their range of m values to include $m < 60$ g and $m > 80$ g. These candidates often increased their values from $m = 60$ g or reduced their chosen values from $m = 80$ g and did not take into account the full range of masses available to them.

Quality of data

(e) (i) Most candidates were awarded credit for the quality of their data. Some candidates could not be awarded credit because they had calculated $h / \cos\theta$ incorrectly.

Table

(d) (ii) 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 for $h / \cos\theta$, omitted the separating mark or recorded the units as "m/°" rather than "m". Many candidates were unsure of the units for $\cos\theta$ or omitted the unit and/or separating mark in the angle heading.

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

Many candidates calculated $h / \cos\theta$ incorrectly either by working out h / θ, $h\cos\theta$ or calculating $\cos\theta$ using the radian (instead of degree) setting on the calculator. Some candidates rounded their answers incorrectly.

Candidates were generally able to record their calculated values for $h / \cos\theta$ to an appropriate number of significant figures.

Graph

(e) (i) The size and scale of the graph axes chosen was generally good so that the plotted points occupied greater than half the graph grid and the scale was easy to read. A minority of candidates drew awkward scales on the y-axis (e.g. multiples of 3.5, 17.2 or 64.3 were 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. Some candidates labelled the axes $h / \cos\theta$ when in fact the values were something different. A few candidates plotted the wrong graph (e.g. m versus h).

Most candidates plotted their points on the graph grid with great care. Others needed to draw the plotted points so that the diameters of the points were equal to, or less than, half a small square (a small pencil cross is recommended). Some candidates can improve by plotting the points more accurately and by ensuring they use a sharp pencil and a straight ruler. The graphs of some candidates were difficult to see because the points were faint or the points had been rubbed out and redrawn many times.

(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. Some lines were forced so that the intercept could be easily read off the y-axis. 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. Candidates should be encouraged to use a clear 30 cm ruler when establishing the position of their line of best fit.

Interpretation of graph

(e) (iii) Many candidates used a suitably large triangle to calculate the gradient, gaining credit for correct read-offs, and substituted into $\Delta y/\Delta x$ to find the gradient. Other candidates needed to check that the read-offs used were within half a small square of the line of best fit, show clearly the substitution into $\Delta y/\Delta x$ (not $\Delta x/\Delta y$), and check that the triangle for calculating the gradient is large enough (the hypotenuse should be greater than half the length of the line drawn). There were many instances of incorrect read-offs, e.g. 186 was read off as 180.6 or 52 was read off as 50.2.

Some candidates were able to correctly read off the *y*-intercept at $x = 0$ directly from the graph. Many candidates read off the *y*-intercept when there was a false origin.

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

Drawing conclusions

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

Some candidates recorded the correct units for *A* (m kg^{-1}) and *B* (m) correctly. A common mistake was to include the angle unit e.g. *A* ($\text{m}\,^\circ\,\text{kg}^{-1}$). A significant number of candidates omitted the units completely.

Question 2

In this question candidates were required to investigate the motion of a loaded wooden rod.

Successful collection of data

(a) (iii) Most candidates recorded values for *x*, *y* and *z* to the nearest millimetre. Some candidates incorrectly stated values to the nearest centimetre when the readings can be measured to the nearest millimetre.

(c) (ii) Many candidates recorded repeat values of *t* with a unit. Some candidates omitted the unit, misread the stopwatch (a reading of 0.20 s read as 0.0020 s), or did not record repeat readings or correctly divide by the number of oscillations taken.

(d) Most candidates kept *y* constant and recorded second values for *x*, *y* and *z*. Most candidates recorded a second value of *T*.

Quality of data

(d) Most candidates recorded a value for *T* which was smaller for the smaller mass m_2.

Display of calculation and reasoning

(b) Some candidates correctly calculated *C* with consistent units. Many other candidates used one unit of mass or length in their calculation and then either stated inconsistent units or did not give any units in the answer.

(c) (iv) Many candidates justified the significant figures they had given for the value of T^2, giving reference to the number of significant figures used their time reading. Some candidates gave reference to 'raw' readings without qualifying what the raw readings were, or related their significant figures chosen to the number used in *x*, *y* and *z*.

(e) (i) Many candidates were able to calculate *k* for the two sets of data, showing their working clearly. A common error was to square the T^2 value already calculated in **(d)**. A minority of candidates incorrectly rearranged the equation to calculate *k*.

Drawing conclusions

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

Estimating uncertainties

(a) (iv) Many candidates were familiar with the equation for calculating percentage uncertainty, though a few candidates made an unrealistically large estimate of the absolute uncertainty in the value of *y*, typically 5 mm or 1 cm. Some candidates repeated their readings and correctly gave the uncertainty in *y* as half the range. Some candidates mistakenly used the value of *z* or *x* as the denominator in the percentage uncertainty calculation for *y*.

Evaluation

(f) Many candidates recognised that two sets of data were insufficient to draw a valid conclusion. Several candidates identified the rod being bent when loaded and suggested using a more rigid rod. Another valid problem was that the rod was difficult to get horizontal (with comparatively few candidates mentioning using a spirit level as a solution).

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 'systematic error', 'parallax error', 'air conditioning', 'faulty apparatus' or 'use an assistant' are not given credit. Some improvements relied heavily on robotic devices and these often did not gain credit e.g. use a 'robotic arm' or a 'mechanical arm'. Other devices without clarification also could not be awarded credit, such as the use of a motion sensor or fiducial marker without reference to its position, the use of a video without reference to some sort of timing device (in this case) or the use of glue without stating what is being fixed to what.

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. Clarity of thought and expression separated very able candidates from less confident and less prepared candidates. Candidates should be encouraged to write about four different problems (perhaps relating to the different measurements undertaken) stating how these difficulties impact on the experiment. Candidates should then be encouraged to think of associated solutions that address these problems, and should not state four solutions to the same problem.

PHYSICS

Paper 9702/34

Advanced Practical Skills 2

Key Messages

- 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. The scale should be chosen so that it is easy to use, and should not be based on multiples of 3, 7 etc.

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

- Well-prepared candidates are able to give many valid limitations and solutions for the last part of **Question 2**. Many weaker and less confident candidates score little or no credit. It is recommended that when learners have carried out an experiment in class (or been shown a demonstration) they address as a group the real problems and solutions that may arise, perhaps by first considering each measurement taken or going through the procedure in order. This can be done at the end of a lesson as a recap and set as homework to consolidate learning.

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. 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. It is essential that a full set of specimen results from the Supervisor are also included with the candidates' scripts.

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

Many candidates demonstrate familiarity with the equation for calculating percentage uncertainties in experimental measurements, but have more difficulty estimating reasonable values for the absolute uncertainty in a measurement. They often confuse the precision of the instrument being used with the absolute uncertainty in the measurement being made. In **Question 2(d)**, candidates were asked to estimate the absolute uncertainty (and then calculate the percentage uncertainty) in the measurement of the time taken for the LED to go out. Many candidates simply quoted the precision of the stopwatch (usually 0.1 s or 0.01 s) ignoring the difficulty in judging when the light actually goes out in a brightly-lit room. A more realistic estimate of the uncertainty in the time measurement might have been anything from 0.5 s to 5 s. One way of estimating the magnitude of random uncertainties is to repeat the measurement, maybe 4 or 5 times, and then use the value of half the range of the measurements as the absolute uncertainty. This simple procedure is perfectly adequate where a small number of measurements is involved.

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 forces in equilibrium.

Successful collection of data

(b) (i) Almost all candidates recorded a value for θ in the range 135° to 165°. A small number of candidates misread the protractor, giving values of θ less than 90°, or gave unjustifiably precise values for θ e.g. 148.2°.

(ii) Most candidates were able to record a value for L in the range 5.0 cm to 10.0 cm. Some Centres used a different spring from that specified in the Confidential Instructions; Examiners were able to take this into account by allowing values for L within 2 cm of the Supervisor's value.

(d) Most candidates were able to collect six sets of values of θ and L without any assistance from the Supervisor. A few candidates did not achieve full credit as their results did not show the correct trend (L should decrease as θ increases).

Range and distribution of values

(d) Stronger candidates made the best use of the range of possible values of θ, by including values of θ both smaller than and greater than the initial value of 150°. Many candidates either moved the two stands steadily further apart (so only obtained values less than the initial value) or only moved the two stands closer together (obtaining values of θ greater than the initial value).

Quality of data

(e) (i) Some candidates were awarded credit for the quality of their data. Other candidates had points which were too scattered. A few candidates obtained an incorrect (negative) trend on their graph, or had calculated values of $1/(\theta - 90°)$ rather than $1/\sin(\theta - 90°)$.

Table

(d) Many candidates set out their tables of results clearly, showing raw values of angle θ and length L followed by the calculated values of $1/\sin(\theta - 90°)$. Some candidates repeated (and then averaged) their measurements, although this is not necessary when taking 'static' measurements. Measurements need only be repeated where there are real variations in the quantity being measured (e.g. the diameter of a plasticine ball) or where there are random uncertainties (e.g. the time taken for a ball to fall a certain height).

Most candidates were awarded credit for using the correct column headings in their tables, giving both the quantity recorded and suitable units for each quantity, with the two separated by a solidus or with the units in brackets. Some candidates did not separate θ from its unit, or gave units for $1/\sin(\theta - 90°)$.

Most candidates recorded their values for L to the nearest 0.1 cm. Others recorded values with an extra zero (i.e. to the nearest 0.1 mm). This precision is not justified for a metre rule.

Most candidates recorded their calculated values for $1/\sin(\theta - 90°)$ to 2 or 3 significant figures, and most calculated values for $1/\sin(\theta - 90°)$ correctly, though a few candidates rounded their answers incorrectly.

Graph

(e) (i) Candidates were required to plot a graph of $1/\sin(\theta - 90°)$ against L. Most candidates gained credit for drawing appropriate axes, with labels and sensible scales. Some candidates chose extremely awkward scales making the correct plotting of points very 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 drew 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 when assessing the straight line of best fit, the anomalous point should be labelled clearly, e.g. by circling the point.

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

(e) (ii) Some candidates were able to draw carefully-considered lines of best fit, but many weaker candidates 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. Judging the line of best fit on a graph is a difficult skill which candidates are advised to practise regularly.

Interpretation of graph

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

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

Several 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 in the table.

Drawing conclusions

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

The majority of candidates recorded correct units for *a* (e.g. cm^{-1} or m^{-1}) and *b* (no units). Others often omitted the units for *a*.

Question 2

In this question, candidates were required to investigate the relationship between the performance of an electrical component (a capacitor) and its volume.

Successful collection of data

(a) (i) Most candidates recorded a value for *d* in the range 5 – 30 mm successfully, giving their answers to the nearest millimetre. A few candidates were not awarded credit because they recorded values to the nearest centimetre.

Almost all candidates recorded a value for l that was greater than *d*.

(c) (iii) Most candidates recorded a value for *t* that was within the range 5.00 s to 30.00 s and had a unit. A few candidates misread the stopwatch, recording values for *t* less than 1.0 s. The majority of candidates repeated their measurement of *t* to find a mean value.

(e) Almost all candidates recorded second values for *d* and l and also a second value of *t*.

Quality of data

(e) Most candidates obtained a smaller value for *t* when using the capacitor with the smaller volume.

Display of calculation and reasoning

(a) (ii) Almost all candidates were able to calculate *V* correctly, though some were not awarded credit because they did not give a correct unit for *V*.

(b) Most candidates were able to justify the number of significant figures given for their answer to **(a)(ii)** in terms of their raw values of *l* and *d*. Some candidates only referred to the 'raw values'; a more detailed answer, stating explicitly which quantities determine the significant figures of *V*, is needed.

(f) (i) The great majority of candidates were able to calculate *k* correctly for the two sets of data, showing their working clearly. A few candidates incorrectly calculated V/t or Vt.

Drawing conclusions

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

Estimating uncertainties

(d) Most candidates were familiar with the equation for calculating percentage uncertainty, though many made too small an estimate of the absolute uncertainty in the value of *t*. Such estimates should take into account the nature of the measurement itself as well as the precision of the instrument being used. As discussed in the General Comments above, the difficulty in judging when the LED goes out (particularly in a brightly-lit room) is much more significant than any uncertainty arising from the precision of the stopwatch.

Evaluation

(g) Many candidates recognised that two sets of data were insufficient to draw a valid conclusion. Several candidates recognised that it was difficult to judge the precise moment that the LED went out. Some suggestions lacked sufficient detail; for example, stating that *d* was difficult to measure accurately, but without giving a valid reason. Answers such as "*d* was difficult to measure because it is small" or "because there is a large percentage uncertainty in measuring *d*" would have gained credit. Vague or generic answers such as 'systematic error', 'parallax error', 'air conditioning', 'faulty apparatus' or 'use an assistant' are not given credit.

Valid improvements included taking more readings (for different sizes of capacitor) and then plotting a suitable graph to test the suggested relationship. Other good answers included placing a cardboard tube over the LED (to see when the LED goes out more clearly) or carrying the experiment out in a darkened room, or using a micrometer or vernier calipers to measure the diameters of the capacitors. Credit is not given for suggestions that could be carried out in the original experiment, such as repeating measurements.

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

- 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. The scale should be chosen so that it is easy to use, and should not be based on multiples of 3, 7 etc.

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

- Well-prepared candidates are able to give many valid limitations and solutions for the last part of **Question 2**. Many weaker and less confident candidates score little or no credit. It is recommended that when learners have carried out an experiment in class (or been shown a demonstration) they address as a group the real problems and solutions that may arise, perhaps by first considering each measurement taken or going through the procedure in order. This can be done at the end of a lesson as a recap and set as homework to consolidate learning.

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. 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. It is essential that a full set of specimen results from the Supervisor are also included with the candidates’ scripts.

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

Careful checking of wire diameter when delivered, the provision of cleaned crocodile clips and testing of meter batteries would be beneficial to candidates in some Centres.

Many candidates were successful in setting up the circuit in **Question 1** and arranging the apparatus for **Question 2**. Some candidates would benefit from further practical work with electrical circuits and use of meters.

Comments on Specific Questions

Question 1

In this question, candidates were required to investigate how the voltage in a circuit varied as the lengths of wire with two different diameters were changed.

Successful collection of data

Successful candidates set up the circuit, attached crocodile clips and noted length and voltage readings.

(b) (i) Successful candidates noted the length *a* to the nearest millimetre and gave a 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 one matching the figure they write down. Candidates were provided with a metre rule reading to the nearest millimetre, so the reading should be given to the nearest millimetre, e.g. 21.3 cm. Readings given as 21.3 (without a unit), 21 cm, 21.30 cm or 21.3 m (inconsistent unit) would not gain credit.

(v) When looking at the range setting on the voltmeter, candidates would see it on the range 0–2 V, reading to the nearest 0.001 V. Some candidates used only 10 mV precision e.g. 1.06 V, suggesting they automatically round their data to 3 significant figures. A few candidates missed units or misinterpreted units, e.g. 1031 V.

Where Supervisor's Results are provided, it is possible to award credit to candidates who have values close to those of the Supervisor.

(c) Successful candidates collected six sets of values for *a*, *b* and *V* showing that as *b* increased, *V* decreased. Candidates generally drew neat and well-constructed tables. Other candidates mixed up *a* and *b* or read from the wrong end of the rules.

Range and distribution of values

(c) Before taking readings, successful candidates benefited from considering the total variation that could be achieved with the apparatus and made changes to length *a* accordingly.

Stronger candidates varied *a* by 30 cm or more, and some used the whole length of 50 cm. Some candidates chose to vary the length by only a few centimetres and were not awarded credit.

Table

(d) When the correct quantity and unit were included in every column heading, candidates were successful. These candidates remembered to include a separating mark, such as a solidus, between the quantity and unit. The majority of candidates were comfortable giving *a* / cm and *b* / cm but some omitted the unit for 1/*V* which should have been (1/V) or V^{-1}.

The metre rule provided had millimetre markings and successful candidates used millimetres when recording their values of *a* and *b*. Values recorded as 0.15 m or 15 cm did not gain credit. Some candidates decide to keep the number of significant figures down the whole column the same, rather than focusing on the precision of readings to the nearest millimetre. These candidates recorded values such as 23.0 cm, 16.0 cm, 7.00 cm, and 4.00 cm; this does not gain credit because the last two values are not recorded to the correct precision.

Most candidates were able to calculate 1/*V* correctly and used 3 s.f. in the raw data for voltage and 3 s.f. for the final value of 1/*V*. 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) voltmeter readings.

Graph

(d) (i) Candidates were asked to plot a graph of 1/*V* on the *y*-axis against *b* on the *x*-axis and good answers gained credit for using axes that were labelled with the quantity, e.g. 1/*V*, and had scales that were simple to use producing points spread over more than half the grid. Considering *b* on the *x*-axis, a scale used by successful candidates had one large square to represent 10 cm so that each small square had a value of 1 cm. An awkward scale on the x-axis was 15 small squares to represent 10 cm, so each square had a value of 0.667; this was not easy to work with and was not awarded credit. Before candidates plot their points they need to consider how much of the grid the points will occupy.

Successful candidates checked that axes were labelled as 1/*V* and *b* rather than omitting the label or writing units only. Candidates gained credit for plotting all the tabulated readings accurately to within half a small square. Successful candidates had access to sharp pencils to draw fine points; any points that have a diameter larger than half a small square are not credited.

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

- check that the point is plotted correctly,
- check that the calculation for that point is correct with no arithmetical error,
- ensure the scale increases regularly and there is no missing value on the axis,
- check the measurements, to be sure the readings were taken and recorded correctly.

Only one point, if any, should be identified as anomalous.

When a line is drawn, successful candidates look at the balance of points around their line. Those candidates who choose to join the first and last points or join up a few points on their line often produce a line which needs to be rotated and cannot be credited as the line of best fit.

Interpretation of graph

(d) (iii) Many candidates have a clear understanding of how to find the gradient and the intercept of a straight line graph.

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). A few candidates gave no indication of read-offs and could not gain credit.

When taking the read-off to find the intercept, successful candidates checked that the *x*-value where the read-off was taken was actually $x = 0$. Often the scale began at, for example $b = 5.0\,\text{cm}$; the candidate assumed because it was the beginning of the grid 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. Candidates should also take care to rearrange the equation correctly, i.e. $c = y - mx$ and not $c = y / mx$.

Drawing conclusions

(e) Candidates were successful when they demonstrated an understanding of how the equation for the graph links to the gradient and intercept. These candidates recognised that, in this case, *P* was equal to the value of the gradient and *Q* was equal to the value of the intercept calculated in **(d)(iii)**. Consequently, they made a direct transfer of the values in **(d)(iii)** to **(e)** and gained full credit. No credit was given for substituting values into the given equation and then solving the simultaneous equations, as the question asked for the values in **(d)(iii)** to be used. No credit was given for *P* and *Q* recorded as fractions.

Correct units were given by successful candidates. Some candidates did not give the unit V^{-1}. Units were often omitted. It was relatively common for candidates to write a unit with the gradient and intercept in **(d)(iii)** but then not to transfer this to *P* and *Q* in **(e)**.

Question 2

In this question, candidates were required to investigate the oscillation of a magnetised nail positioned in the magnetic field between two permanent magnets.

Successful collection of data

(b) (iv) Most candidates successfully met the challenge of setting up the arrangement and recorded a value for *x* to the nearest millimetre, in range, with consistent units. Successful candidates noticed that they needed to write a unit on the answer line.

Measuring the distance between the magnets was a static observation. Candidates could take all the precautions they needed to produce an accurate measurement, such as placing the scale close to the magnets, lining up their head above the scale on the metre rule (which was accurately calibrated to the nearest mm) and taking time to make the observation. Consequently, this measurement was not regarded as a major source of uncertainty.

(c) (i) The protractor could only be read to the nearest degree. Candidates needed to read the question carefully, and they then were able to achieve success by positioning the rod so that the value of θ was in the acceptable range.

(d) (ii) Successful candidates recorded the time for several swings n, divided by n to find a value for T and stated this value with the correct unit ‘s’. Many candidates had difficulty reading the stopwatch correctly and gave answers which were out of range. Most candidates repeated their readings.

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

Quality of data

(f) Successful candidates found that when θ was increased, the value of T_1/T_2 decreased.

Display of calculation and reasoning

(c) (iii) Stronger candidates correctly calculated a value for $\cos^2(\theta/2)$, giving the final value to 2 or 3 significant figures. Some candidates did not square the cosine or squared the angle before taking the cosine. A few candidates were not awarded credit because they stated a bald ‘1’ as their answer.

(c) (iv) A correct statement was that the value of $\cos^2(\theta/2)$ was given to the same number of significant figures as (or one more than) the value of θ. Candidates must explicitly state θ (i.e. the quantity relevant to the question) in their answer; phrases such as “raw data” or “the value in the calculation” did not gain credit.

(g) (i) Many candidates successfully rearranged the equation and calculated k for both experiments. Some candidates misunderstood how to rearrange and used $k = [\cos^2(\theta/2)]/(T_1/T_2)$. Successful candidates gave their answers to 2 or 3 s.f. A common mistake was to round both values to one significant figure so that both k values were identical, but this could not be awarded credit. Some candidates retake their measurements at this stage. If this is done, the new values need to be used and taken through in the calculation of k.

Drawing conclusions

(g) (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 **(c)(ii)**. 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”.

Estimating uncertainties

(c) (ii) Most candidates were familiar with the equation for calculating percentage uncertainty, though only a small number made a realistic estimate of the absolute uncertainty in θ i.e. 2° to 5°. Successful candidates realised that the absolute uncertainty in the value of θ depends not only on the precision of the measuring instrument (the protractor read to 1°) but also on the nature of the experiment itself. The measurement of θ presented a challenge owing to the distance between the rod and the protractor. Estimates of the absolute uncertainty in the value of θ of 1° or 0.1° were unrealistic. Many candidates stated the uncertainty as 1°, the smallest reading on the protractor, and were not awarded credit.

When repeat readings were noted, the absolute uncertainty could be calculated as half the range of the repeated values. The half-range calculation needed to be shown so that it was clear how the estimate of absolute uncertainty had been produced.

Evaluation

(h) The experiment in **Question 2** is designed to have problems. Successful candidates thought about these problems while doing the experiment and made valid suggestions to overcome them. The key to success in this section is for candidates to identify genuine problems associated with taking accurate readings during the experiment. Three areas that could be considered here were the angle θ, short periodic time T and sources of inaccuracy associated with the oscillations.

Two readings are not enough to draw a conclusion. Simply stating that “two readings are not enough” did not gain credit. Successful solutions gained credit for the suggestion “take more readings and plot a graph”.

Successful candidates noticed that the thick rod was positioned well above the protractor. A suggestion that it was difficult to measure θ owing to this separation was valid. Stronger candidates considered how to overcome this, perhaps by using pendulums with bobs near the protractor. Candidates often stated that “the measurement of θ was difficult”, which is true but not sufficient: an appropriate reason for the difficulty was needed.

The periodic time was short and therefore there would be a large percentage uncertainty in the time. When considering the solution, successful candidates suggested using a “video with a timer” or “video viewing frame by frame”. Just ‘video’ on its own was not sufficient to gain credit. Successful candidates also noticed that air movement could affect the rotation of the nail and consequently the time of the oscillation.

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. Vague or generic statements about ‘systematic errors’, ‘zero errors’, ‘air resistance’ etc. did not gain credit, and neither did generic solutions such as ‘use an assistant’. Candidates should avoid making suggestions that should already have been done as part of the experiment, such as repeating measurements and calculating averages.

PHYSICS

Paper 9702/36

Advanced Practical Skills 2

Key Messages

- 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. The scale should be chosen so that it is easy to use, and should not be based on multiples of 3, 7 etc.

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

- Well-prepared candidates are able to give many valid limitations and solutions for the last part of **Question 2**. Many weaker and less confident candidates score little or no credit. It is recommended that when learners have carried out an experiment in class (or been shown a demonstration) they address as a group the real problems and solutions that may arise, perhaps by first considering each measurement taken or going through the procedure in order. This can be done at the end of a lesson as a recap and set as homework to consolidate learning.

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. 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. It is essential that a full set of specimen results from the Supervisor are also included with the candidates’ scripts.

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

Skills in making measurements and presenting data were evident for most candidates, and many also demonstrated good evaluation ability.

Comments on Specific Questions

Question 1

In this question, candidates were asked to investigate the forces on a partially submerged flask.

Successful collection of data

(a) Almost all candidates recorded a value in the expected range for the height H of the conical flask.

(c) (iii) Although most candidates recorded the newton-meter reading F to the nearest 0.1 N, a small number recorded very large values such as 320 N, possibly suggesting that they had read a scale marked in grams.

(iv) Candidates were instructed to start with approximately 4 cm of the flask submerged. Most did this carefully and calculated a value for *x* in the range 3.5 cm to 4.5 cm.

Range and distribution of values

(d) Around half the candidates made good use of the range of possible values of submersion depth, ensuring that the difference between the smallest and largest values of *x* was 6 cm or more.

Quality of data

(e) (i) Most candidates were awarded credit for the quality of their data.

Table

(d) Most tables were neat and clear and contained all five required columns of data.

Column headings were generally always included, but weaker candidates omitted the unit for one of their columns (e.g. cm^3 for the $(H–x)^3$ column).

Values for h_w and h_b should have been recorded to the nearest millimetre (the precision of the metre rule or ruler). In some cases an incorrect zero was added, for example 11.90 cm.

Values for $(H–x)^3$ were nearly always calculated correctly, with just a few rounding errors.

Many candidates had difficulty deciding how many significant figures to give for their $(H–x)^3$ values, and how best to indicate their choice. If one of the terms in a calculation is the difference between two measurements, the result of this subtraction should be considered when deciding how many significant figures to give for the final result. For example, in the calculation 15.6(21.2 – 19.4) all the numbers have 3 s.f. but the term in brackets has the value 1.8 and this has only 2 s.f. Therefore the final result should be given to 2 (or 3) sig. fig., i.e. 28 (or 28.1).

Graph

(e) (i) For their graph of *F* against $(H–x)^3$, most candidates used simple and sensible scales. The only common error was to insist on including the origin, with the result that plotted points were compressed into too small an area of the grid. The few candidates who chose awkward scales found that the correct plotting of points was difficult, and often made errors when reading off values to calculate gradient or intercept. A small number of candidates used non-linear scales, and these cannot be awarded credit for the axes or for the quality of data (as this cannot be judged).

Many candidates gained credit for plotting their tabulated readings correctly, and for labelling a single point if they felt that it was anomalous and should not be considered when drawing a line of best fit. In one or two cases the candidate labelled the axes correctly but plotted data from the wrong column in their table (e.g. *x* values instead of *F* values).

(ii) Lines of best fit were generally chosen well and drawn clearly, without any kinks or changes of gradient. Candidates should be encouraged to use a clear 30 cm ruler when establishing the position of their line of best fit.

Interpretation of graph

(e) (iii) Candidates were generally successful in finding the gradient and intercept of their line. There were just a few mistakes with reading coordinates, or with reading an intercept value directly from the axis when the graph had a false origin (instead of substituting coordinate values into $y = mx + c$).

Drawing conclusions

(f) Most candidates recognised that *a* was equal to the value of the gradient and *b* was equal to the value of the intercept. A few candidates ignored the instruction to use values from **(e)(iii)** and instead tried to calculate *a* and *b* by first substituting values into the given equation and then solving the simultaneous equations. No credit is given for this as the question specifically asks for the answers in **(e)(iii)** to be used.

A large number of candidates included correct units for *a* and *b*.

Question 2

In this question, candidates were required to investigate the speed of rolling of an axle with a flywheel attached.

Successful collection of data

(a) (i) Candidates were required to measure the axle diameter using a micrometer. Many recorded sensible values to the correct precision, but a significant number of candidates would benefit from more experience in using this measuring instrument. There were many power-of-ten errors in their recorded measurements.

(ii) When asked to measure the flywheel diameter, most candidates successfully carried out this awkward task and recorded a sensible value to the correct precision.

(b) Having been asked to set the upper end of the track approximately 8 cm above the bench, candidates were required to measure this height *h* as well as they could. Most gave a value to the nearest millimetre between 7.5 cm and 8.5 cm, but a few candidates were as much as 5 cm outside this range, suggesting that they had not read the instruction carefully.

(c) (ii) Since variation between the condition of different tracks and flywheels was expected to result in wide differences between rolling times, the value of *t* itself was not assessed. Nearly all candidates included a unit for their value, and a majority gained additional credit for finding the average of repeated readings.

Quality of data

(d) (ii) After increasing the axle diameter, candidates were asked to repeat the timing exercise. The majority correctly found the expected trend that increased axle diameter led to faster rolling.

Display of calculation and reasoning

(c) (iv) When asked to calculate a value for *g*, nearly all candidates carried out the arithmetic procedure correctly. Some candidates either omitted a unit or gave the wrong unit (m s^{-2} instead of cm s^{-2} or vice versa).

(e) (i) The great majority of candidates were able to calculate *k* values correctly from the two sets of data.

(ii) Most candidates understood that the significant figures in *k* depended on the significant figures in their measurements, but some did not name both *t* and *d* as the relevant measured values.

Drawing conclusions

(e) (iii) The comparison of the two values of *k* and the evaluation of the suggested relationship was often done well, with a clear criterion against which the comparison was judged. The terminology used was not always accurate – "percentage uncertainty in *k*" was frequently used when referring to the percentage difference between the two *k* values that had been calculated.

Estimating uncertainties

(c) (iii) The value of *t* was measured using a stopwatch with a precision of 0.1 s or 0.01 s, but the uncertainty in the measurement was much greater than this because of the human operator. Examiners accepted an uncertainty in the range 0.2 s to 0.5 s, and credit was given if this was then expressed as a percentage of *t*.

The alternative approach of looking at the scatter of repeated measurements (in terms of half the range of values) was also credited as the uncertainty when expressed as a percentage of *t*.

Evaluation

(f) Many candidates thought carefully about this section and were able to gain credit. The majority of candidates recognised that two sets of data were insufficient to draw a valid conclusion, and went on to suggest taking more readings and plotting a graph.

Many candidates were concerned about the force that had to be applied to start the axle rolling, and a large number went on to say that this force could vary (and affect the measured time). Suggested improvements often lacked detail and only outlined the use of a ‘mechanical hand’ or similar. The idea of using a steeper ramp (so that a starting force was not needed) was given credit.

The measurement of t was not very difficult, but changes which would improve reliability were credited. These included timing using sensors (e.g. light gates) as long as the positioning was described.

A common mistake was to describe lubricating or smoothing the track to reduce friction. In this experiment, friction is necessary to cause the rolling that is being investigated.

The measurement of the flywheel diameter D was difficult because the axle prevented a ruler being positioned along a diameter, and several candidates identified this as a potential cause of parallax error. Most of them went on to suggest the use of calipers.

Several candidates pointed out that the plastic tubing used to increase the axle diameter was not ideal as it could compress when the diameter was measured, and a few of these suggested using a new, larger axle as an alternative.

PHYSICS

Paper 9702/41
A2 Structured Questions

Key Messages

- Where candidates have a good level of subject knowledge, they can improve further by applying this knowledge to problem-solving. Candidates would, in general, benefit from a wider experience of solving questions from past papers.
- Candidates need to explain their work fully. In particular, where an answer is given in the question, relevant formulae should be quoted and full substitution of values made clear. Candidates often lose credit where working is not shown clearly.
- 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

Well-prepared candidates appeared to have sufficient time to complete their answers. There were few scripts where all parts of the questions had not been attempted.

Comments on Specific Questions

Section A

Question 1

(a) (i) For full credit, candidates needed to provide an explanation. Some candidates did not give any explanation. Others equated the centripetal and gravitational forces in a way that gave a misleading impression that the satellite is in equilibrium.

(ii) Most candidates knew the relevant equation but a common mistake was to omit the negative sign.

(iii) Most candidates added the answers in **(a)(i)** and **(a)(ii)**. A large number found it difficult to simplify the resulting expression.

(b) Only a small number of candidates were able to provide correct responses to all four parts of this question. A common misunderstanding was to quote the total energy as being constant.

Question 2

(a) In most scripts, the equation $pV = nRT$ was quoted. Many candidates did not give any explanation of the symbols. In particular, it was not stated that T represents the thermodynamic (kelvin) temperature.

(b) (i) Many candidates gave the temperature rise as 321 K, rather than 48 K.

(ii) Most candidates knew the relationship between $\langle c^2 \rangle$ and T. Many then used temperature in Celsius. In those answers where $\langle c^2 \rangle$ was calculated correctly, it was relatively common to find that the root-mean-square value was not determined.

Question 3

(a) Most candidates knew the relationship but did not make clear the directions of the energy changes.

(b) (i) Candidates were instructed to use the terms in **(a)** but many instead referred to kinetic energy and potential energy. There were frequent statements that no thermal energy is required because the temperature remains constant.

(ii) Only the strongest candidates appreciated that no thermal energy would enter or leave the system because the change takes place in a very short time. There were a small number of correct answers based on work done by the gas, resulting in a decrease in internal energy.

Question 4

(a) The explanation of free oscillations was correct in most scripts although some answers were a paraphrase of the question. The explanation of forced oscillations proved to be more difficult.

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

(ii) Answers to this section very rarely linked an explanation to the shape of the graph. Many candidates discussed some aspect of friction as the trolley moves but did not refer to Fig. 4.2. Candidates should be reminded that, where a question asks for reference to a specific figure, this is essential to receive full credit.

(c) Correct answers were common. A common misconception amongst weaker candidates was to try to produce an answer using the equation $v = f\lambda$.

Question 5

(a) (i) In general, Coulomb's law was quoted correctly, with a reference to point charges. A significant minority of weaker candidates made reference to mass rather than charge.

(ii) 1. Candidates should be encouraged to be as precise as possible in describing a direction. Some responses were not precise. 'Away from the sphere' could describe many different directions and 'radially away from the sphere' would be a better answer.

2. It was expected that a statement to the effect that $x = r$ would be made. As in **part 1**, some statements were not precise. Answers such as 'near to the sphere' or 'next to the sphere' were common and could not be credited.

3. In general, candidates who quoted an expression for the force did arrive at the ratio of 16 although an answer of 1/16 was relatively common. An answer of 4 was seen quite frequently where an appropriate equation for force was not quoted.

(b) There was some confusion here. A large number of candidates quoted either $E = V / d$ or $V = Q / 4\pi\varepsilon_0 x$ or $C = Q / V$ and then substituted the field strength for V.

Question 6

(a) (i) The correct answer of mg was seen in some scripts. Frequently, the force was said to be 'downwards', with no reference to the direction of the field lines.

(ii) There were very few correct answers. Most candidates assumed that a force would be present and then went on to describe this force.

(b) (i) A careful distinction between field and force is necessary. It was common to find a statement to the effect that the magnetic field, acting upwards, must balance the electric field (or the electric force) acting downwards.

(ii) Explanation was essential when answering this question. In many scripts, the starting point was $BQv = EQ$, without any further identification of the forces or quantities.

(c) The majority of sketches showed no deviation for at least the first 1 cm of the path within the field. A common mistake was to show a deviation in the wrong direction.

Question 7

(a) It was expected that a reference would be made to incident electromagnetic radiation. Many candidates stated only that the threshold frequency is the ‘minimum frequency’.

(b) There were some answers where reference was made to energy to bring an electron to the surface of the metal. Many candidates did not consider the electrons to be free within the body of the metal and consequently referred to electron shells and energy levels.

(c) (i) A very common mistake was to use the value of $1/\lambda$ at the end of the line, rather than to determine the intercept on the $1/\lambda$ axis.

(ii) This question was generally answered well, using the value for the threshold frequency determined in **(c)(i)**.

(d) It was important that the line drawn was parallel to the given line. Some candidates did not draw the line carefully.

Question 8

(a) In many instances, the answer for the description of the nucleus did not indicate that the nucleus occupies a very small proportion of the total volume of the atom. There was confusion between nucleon and nucleon number, with many candidates stating that a nucleon is the number of protons and neutrons found in a nucleus.

(b) (i) Both parts of this calculation were completed successfully by the majority of candidates.

(ii) There were many correct answers here. The most usual mistake was to calculate correctly the amount in mol and then omit the Avogadro constant.

Section B

Question 9

(a) (i) Answers were generally correct.

(ii) The great majority of candidates calculated the potential difference across the thermistor but did not calculate the potential at point B.

(iii) The same error was often made here as was made in **(a)(ii)**.

(b) Many candidates gave very general answers, stating that the thermistor resistance would decrease as the temperature rises and that the output would change polarity. Values were not often given for either input or output voltages. The sudden switch in polarity of the output was not described.

Question 10

(a) The meaning of *sharpness* was known widely. As regards *contrast*, the importance of differences in blackening was often not made apparent.

(b) (i) Candidates found it difficult to give an explanation. Many stated that 80 keV would be the energy of the X-ray photons, without any maximum being mentioned. Others thought that 80 keV would be the voltage through which the electrons would be accelerated.

(ii) This was completed successfully by many, but power-of-ten errors were common.

(c) In many answers, candidates concentrated on the relative magnitudes of the absorption coefficients. The calculation in **(b)(ii)** was intended to encourage candidates to think about thickness in addition to the coefficient. Very few realised that the relevant quantity is μx.

Question 11

(a) There were some comprehensive answers but others did not distinguish clearly between the functions of the carrier wave and the information wave.

(b) This question was relatively straightforward, and candidates who have studied this part of the syllabus should have been able to perform well. Some candidates produced numbers which appeared to be guesswork. These candidates would benefit from further work on this part of the syllabus.

Question 12

(a) (i) Most answers were acceptable. A small number gave an inappropriate answer based on ‘energy’ or ‘signal’.

(ii) There were many references to noise, but some candidates stated that noise did not exist in digital signals. There was often vague terminology introduced such as ‘filtered’ or ‘reduced’. Quite frequently, reference was made to data transmission being ‘faster’. It was not clear whether this meant speed of signal or of data handling.

(b) There were many correct answers to this calculation. The most common problem was confusion between gain and attenuation, resulting in negative signs which were ignored in the final answer.

PHYSICS

Paper 9702/42

A2 Structured Questions

Key Messages

- Where candidates have a good level of subject knowledge, they can improve further by applying this knowledge to problem-solving. Candidates would, in general, benefit from a wider experience of solving questions from past papers.

- Candidates need to explain their work fully. In particular, where an answer is given in the question, relevant formulae should be quoted and full substitution of values made clear. Candidates often lose credit where working is not shown clearly.

- 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

Well-prepared candidates appeared to have sufficient time to complete their answers. There were few scripts where all parts of the questions had not been attempted.

Comments on Specific Questions

Section A

Question 1

(a) (i) For full credit, candidates needed to provide an explanation. Some candidates did not give any explanation. Others equated the centripetal and gravitational forces in a way that gave a misleading impression that the satellite is in equilibrium.

(ii) Most candidates knew the relevant equation but a common mistake was to omit the negative sign.

(iii) Most candidates added the answers in **(a)(i)** and **(a)(ii)**. A large number found it difficult to simplify the resulting expression.

(b) Only a small number of candidates were able to provide correct responses to all four parts of this question. A common misunderstanding was to quote the total energy as being constant.

Question 2

(a) In most scripts, the equation $pV = nRT$ was quoted. Many candidates did not give any explanation of the symbols. In particular, it was not stated that T represents the thermodynamic (kelvin) temperature.

(b) (i) Many candidates gave the temperature rise as 321 K, rather than 48 K.

(ii) Most candidates knew the relationship between $<c^2>$ and T. Many then used temperature in Celsius. In those answers where $<c^2>$ was calculated correctly, it was relatively common to find that the root-mean-square value was not determined.

Question 3

(a) Most candidates knew the relationship but did not make clear the directions of the energy changes.

(b) (i) Candidates were instructed to use the terms in **(a)** but many instead referred to kinetic energy and potential energy. There were frequent statements that no thermal energy is required because the temperature remains constant.

(ii) Only the strongest candidates appreciated that no thermal energy would enter or leave the system because the change takes place in a very short time. There were a small number of correct answers based on work done by the gas, resulting in a decrease in internal energy.

Question 4

(a) The explanation of free oscillations was correct in most scripts although some answers were a paraphrase of the question. The explanation of forced oscillations proved to be more difficult.

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

(ii) Answers to this section very rarely linked an explanation to the shape of the graph. Many candidates discussed some aspect of friction as the trolley moves but did not refer to Fig. 4.2. Candidates should be reminded that, where a question asks for reference to a specific figure, this is essential to receive full credit.

(c) Correct answers were common. A common misconception amongst weaker candidates was to try to produce an answer using the equation $v = f\lambda$.

Question 5

(a) (i) In general, Coulomb's law was quoted correctly, with a reference to point charges. A significant minority of weaker candidates made reference to mass rather than charge.

(ii) 1. Candidates should be encouraged to be as precise as possible in describing a direction. Some responses were not precise. 'Away from the sphere' could describe many different directions and 'radially away from the sphere' would be a better answer.

2. It was expected that a statement to the effect that $x = r$ would be made. As in **part 1**, some statements were not precise. Answers such as 'near to the sphere' or 'next to the sphere' were common and could not be credited.

3. In general, candidates who quoted an expression for the force did arrive at the ratio of 16 although an answer of 1/16 was relatively common. An answer of 4 was seen quite frequently where an appropriate equation for force was not quoted.

(b) There was some confusion here. A large number of candidates quoted either $E = V / d$ or $V = Q / 4\pi\varepsilon_0 x$ or $C = Q / V$ and then substituted the field strength for V.

Question 6

(a) (i) The correct answer of mg was seen in some scripts. Frequently, the force was said to be 'downwards', with no reference to the direction of the field lines.

(ii) There were very few correct answers. Most candidates assumed that a force would be present and then went on to describe this force.

(b) (i) A careful distinction between field and force is necessary. It was common to find a statement to the effect that the magnetic field, acting upwards, must balance the electric field (or the electric force) acting downwards.

(ii) Explanation was essential when answering this question. In many scripts, the starting point was $BQv = EQ$, without any further identification of the forces or quantities.

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(a) It was expected that a reference would be made to incident electromagnetic radiation. Many candidates stated only that the threshold frequency is the 'minimum frequency'.

(b) There were some answers where reference was made to energy to bring an electron to the surface of the metal. Many candidates did not consider the electrons to be free within the body of the metal and consequently referred to electron shells and energy levels.

(c) (i) A very common mistake was to use the value of $1/\lambda$ at the end of the line, rather than to determine the intercept on the $1/\lambda$ axis.

(ii) This question was generally answered well, using the value for the threshold frequency determined in **(c)(i)**.

(d) It was important that the line drawn was parallel to the given line. Some candidates did not draw the line carefully.

Question 8

(a) In many instances, the answer for the description of the nucleus did not indicate that the nucleus occupies a very small proportion of the total volume of the atom. There was confusion between nucleon and nucleon number, with many candidates stating that a nucleon is the number of protons and neutrons found in a nucleus.

(b) (i) Both parts of this calculation were completed successfully by the majority of candidates.

(ii) There were many correct answers here. The most usual mistake was to calculate correctly the amount in mol and then omit the Avogadro constant.

Section B

Question 9

(a) (i) Answers were generally correct.

(ii) The great majority of candidates calculated the potential difference across the thermistor but did not calculate the potential at point B.

(iii) The same error was often made here as was made in **(a)(ii)**.

(b) Many candidates gave very general answers, stating that the thermistor resistance would decrease as the temperature rises and that the output would change polarity. Values were not often given for either input or output voltages. The sudden switch in polarity of the output was not described.

Question 10

(a) The meaning of *sharpness* was known widely. As regards *contrast*, the importance of differences in blackening was often not made apparent.

(b) (i) Candidates found it difficult to give an explanation. Many stated that 80 keV would be the energy of the X-ray photons, without any maximum being mentioned. Others thought that 80 keV would be the voltage through which the electrons would be accelerated.

(ii) This was completed successfully by many, but power-of-ten errors were common.

(c) In many answers, candidates concentrated on the relative magnitudes of the absorption coefficients. The calculation in **(b)(ii)** was intended to encourage candidates to think about thickness in addition to the coefficient. Very few realised that the relevant quantity is μx.

Question 11

(a) There were some comprehensive answers but others did not distinguish clearly between the functions of the carrier wave and the information wave.

(b) This question was relatively straightforward, and candidates who have studied this part of the syllabus should have been able to perform well. Some candidates produced numbers which appeared to be guesswork. These candidates would benefit from further work on this part of the syllabus.

Question 12

(a) (i) Most answers were acceptable. A small number gave an inappropriate answer based on 'energy' or 'signal'.

(ii) There were many references to noise, but some candidates stated that noise did not exist in digital signals. There was often vague terminology introduced such as 'filtered' or 'reduced'. Quite frequently, reference was made to data transmission being 'faster'. It was not clear whether this meant speed of signal or of data handling.

(b) There were many correct answers to this calculation. The most common problem was confusion between gain and attenuation, resulting in negative signs which were ignored in the final answer.

PHYSICS

Paper 9702/43

A2 Structured Questions

Key Messages

- Where candidates have a good level of subject knowledge, they can improve further by applying this knowledge to problem-solving. Candidates would, in general, benefit from a wider experience of solving questions from past papers.
- Candidates need to explain their work fully. In particular, where an answer is given in the question, relevant formulae should be quoted and full substitution of values made clear. Candidates often lose credit where working is not shown clearly.
- 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

There were some difficult and subtle explanations needed at various points in this paper and this was the area where candidates had the most difficulty. Calculations and definitions were generally well done.

Some candidates were able to perform very well on ***Section B***. However, the candidates in some Centres left the last four questions blank. Candidates in these Centres would benefit from further preparatory work on the areas of the syllabus covering applications of physics.

Comments on Specific Questions

Section A

Question 1

(a) This law was usually well stated but many responses missed the reference to point masses.

(b) Weaker candidates tried to rearrange the expression given, and a number of candidates lost credit because they introduced a symbol *r* without defining it.

(c) Many candidates attempted a single point solution rather than using the gradient of the graph. The weakest candidates often made no attempt to convert km^3 to m^3 or to convert day^2 to s^2. Those who did attempt the two conversions found them difficult, and often made errors in one or both.

Question 2

(a) The most common answers were 'no intermolecular force' and 'random motion of the molecules'. Many candidates referred to particles rather than molecules as stated in the stem of the question. Some candidates did not read the question carefully and mentioned that the molecules had elastic collisions.

(b) Many candidates simply wrote that $\langle c^2 \rangle$ is the mean-square speed but this was not itself an answer to the question. Credit could be given for a comment on the range of velocities of gas molecules. Some referred to *c* as the speed of light and candidates should realise that this is impossible.

(c) (i) The formulae in **(b)** used the symbol *n* to represent the number of molecules per unit volume and this was clearly stated. Candidates often confused this with the standard symbol *n* to represent the number of moles. Many candidates derived expressions that were incorrect by a factor equal to the Avogadro number.

(ii) The key point in answering this question was to realise that the mean-square speed is proportional to the absolute temperature. Sometimes the physics given was incorrect owing to the use of temperature values in units of °C rather than K. Some candidates assumed that the volume of the gas remained constant without explicitly explaining this assumption. Occasionally candidates used $(1/2)m\langle c^2\rangle = (3/2)kT$ and found the mass of a molecule as part of their calculation. This was a valid method, but long-winded and therefore prone to arithmetic error.

Question 3

(a) There were many good answers. The weakest candidates sometimes confused temperature and thermal energy and so referred to the two bodies having the same thermal energy. Other mistakes included referring to 'energy' without saying what type of energy and referring to the bodies having 'constant temperature' rather than explaining that each body had the same temperature.

(b) (i) Many candidates gave the correct answer. Some candidates added 273.15 K to their initially correct answer.

(ii) Many candidates did not use an appropriate number of decimal places. Some added 273 rather than 273.15.

(c) Even the weakest candidates were able to calculate the value for the total change in kinetic energy. The calculation of work done proved more difficult, with some candidates making a power-of-ten error when substituting the value of the change in volume. The sign convention for the first law of thermodynamics was often ignored and this meant that the value of work done was substituted with the wrong sign.

Question 4

(a) Most candidates appeared to be well prepared and scored full credit for the definition here.

(b) The less able candidates simply started with 'density = mass / volume' and then inappropriately used the density of the water, the total mass of the tube and contents, and the volume of the submerged part of the tube. Very able candidates sometimes used Archimedes' principle to equate the weight of the displaced water to the weight of the tube, but did not always fully answer the question because they did not refer to the liquid pressure on the base of the tube. Some candidates made power-of-ten errors between kg and g and between m and cm.

(c) (i) 1. Common mistakes included wrong powers of ten, not taking the square root of the angular velocity and not halving the period to find the time t_1.

2. Nearly all candidates were awarded credit.

(ii) Fully correct answers were rare. A common error was to calculate the difference in the kinetic energy at the two times. Since the kinetic energy is zero at each of the two times, the difference in kinetic energy is also zero. Another common error was to use the value of the distance *h* rather than the value of the amplitude x_0 in the expression for the total energy of the oscillation. Some weaker candidates incorrectly thought that the loss in total energy could be calculated by the expression $mg(h_2 - h_1)$.

Question 5

(a) Most candidates were able to receive at least partial credit.

(b) There were various different methods that could be used, as given in the mark scheme. The method using average field strength was not commonly used. The method using $V = Ex$ was more common but many candidates wrongly used $\Delta V = \Delta E \times \Delta x$. Some candidates attempted to use a method involving the charge on the sphere, but sometimes made the mistake of using either

8.5×10^{-9} C or 1.6×10^{-9} C as the charge on the sphere rather than calculating the charge on the sphere first.

Question 6

(a) This question needed to be answered in terms of magnetic flux density. Many candidates used flux, force or current instead. Candidates stating that the fields were 'equal' needed to say that they are equal in magnitude.

(b) Candidates found this question difficult. Although candidates often referred to flux being cut, they rarely stated explicitly that it was the solenoid that was cutting the flux. For most candidates this was challenging, perhaps because they were more familiar with the idea of a permanent magnet interacting with a simple coil of wire.

Question 7

(a) Most candidates gave correct answers, but some left their answers in terms of $\sqrt{2}$ and π. Candidates should be encouraged always to calculate the answer.

(b) Many candidates wrote about the use of a capacitor in smoothing. Stronger candidates were able to link the large capacitance with a large charge and go on to explain that, as current is charge per unit time, a large charge will produce a large current. A small number made the link with the high frequency giving rise to a very short charging/discharging time.

Question 8

(a) The equation was usually stated correctly, although sometimes one of the terms in the equation had an incorrect sign. Those candidates who could not recall this formula often found the remainder of the question difficult.

(b) (i) Some weaker candidates thought that the gradient was $E_{MAX} \times \lambda$. Many of those who did correctly identify the gradient as equal to hc did not state that h and c are both constant.

(ii) Most candidates were able to obtain credit here, including remembering to convert the work function energy from units of eV to J.

Question 9

(a) Candidates needed to give precise statements. It is incorrect to state that the binding energy is the energy required to separate a nucleon to infinity. There is also a common misconception that it is the energy needed to hold the nucleons together in the nucleus.

(b) (i) There were very few fully correct answers. Some candidates referred to elements or isotopes rather than nuclei. Others referred to a single atom or a nucleus rather than atoms or nuclei.

(ii) Most candidates were able to answer correctly.

(c) (i) There were many correct answers. When a question asks candidates to 'show that', they must ensure that all steps in their answer are clear. Sometimes the conversion from years to seconds was not shown. Some candidates used a number of 360 days in a year.

(ii) The calculation of the number of nuclei was generally done well. The calculation of the mass of the sample was more problematic. Some candidates confused kg and g and so gave the answer as 63 g.

Section B

Question 10

(a) This question was well answered, with common mistakes being to miss out the arrows on the LED symbol completely, or to have them facing the wrong way.

(b) Candidates who correctly understood how each component would contribute to the overall functioning of the circuit stood a greater chance of scoring highly than candidates who simply tried to redraw the circuit from memory without any real understanding. The symbol for the relay coil was often confused with the symbol for a resistor. Stronger candidates sometimes added a protective diode in parallel with the relay coil, although there were some cases where the protective diode was given, but the main diode in the V_{OUT} line was missed out.

Question 11

(a) The most common correct answers were scattering and reflection. Some candidates did not read the question carefully and so referred to absorption in the metal plate. Common answers that were not credited included ionisation/absorption in the air and simply stating that A is closer than B to the X-ray source.

(b) (i) The most common error was to have the ratio inverted and arrive at 0.34 and 0.0057. A few candidates converted the cm to m without also converting μ, which lead to two ratios very close in value instead of significantly different.

(ii) Candidates were required to refer to their previous answers here and many did not. Some just referred to the attenuation coefficient or stated that there would be good contrast from their general knowledge with no evidence for this statement. For full credit, candidates needed to explain what the ratios were and to make a comparison between the two calculated values.

Question 12

(a) This was a straightforward question where many candidates gained full credit. Inspecting the diagram carefully should have alerted candidates to the first two of the answers, and for many it obviously did. A small number wrote RF amplifier, but the question refers to a speech system.

(b) Many candidates answered well. The most common wrong answer for **(i)** was 5. The signal did not go above 15, so 4 bits would be sufficient to encode the voltage levels.

(c) Many weaker candidates obtained partial credit for the first 5 correct levels. Sometimes the output level at time 1.25 ms was incorrectly rounded up to 8 rather than rounded down to 7. Although most candidates realised that the output would exist as a series of steps of depth 0.25 ms, sometimes these were drawn in the wrong intervals (0.25 ms too early).

Question 13

(a) Candidates often stated that a polar orbiting satellite has the advantage of coverage at the poles or greater coverage, but did not mention that this is only true over a (long) time period. A common misconception is that polar orbiting satellites cannot provide coverage at the equator.

(b) (i) Weaker candidates sometimes thought that 6/4 GHz referred to the bandwidth of either the uplink or of the downlink. Other candidates said that 6 GHz was the received frequency and 4 GHz is the transmitted frequency without making it clear what was receiving and transmitting the signal.

(ii) Some candidates wrote that the uplink was attenuated, but did not stress that it was greatly attenuated. Sometimes the answers were ambiguous and it was not clear whether the different frequencies were to prevent the downlink swamping the uplink or vice versa.

PHYSICS

Paper 9702/51

Planning, Analysis and Evaluation

Key Messages

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

General Comments

All candidates completed the paper and there was no evidence of time constraints. The majority of the scripts were clearly written. In general, graphs were well drawn with points and error bars easily identifiable. There was improvement in the presentation of mathematical working. Some candidates find the appropriate use of significant figures difficult. Skills required for describing experiments are best learnt from 'hands on' experience. In **Question 2** the treatment of uncertainties is not always fully understood.

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

Comments on Specific Questions

Question 1

Candidates were required to design a laboratory experiment to investigate how the angle ϕ at which a cylinder topples varies with the mass m of oil in the cylinder. Candidates were also required to verify the given equation and explain how the constants a and b could be determined from the measurements. In general the description of the experiment by candidates has improved. Some candidates stated that they would change the angle and measure the corresponding mass of oil.

Most candidates correctly identified the independent and dependent variables. Many candidates scored further credit for stating that the diameter of the cylinder needed to be kept constant. Fewer candidates considered that the temperature of the oil needed to be kept constant.

Five marks are available for the methods of data collection. Credit was awarded for a clearly labelled diagram. Diagrams should include the necessary pieces of apparatus set up as they would be used in the experiment. In this case a labelled protractor needed to be correctly positioned as the cylinder was about to topple. Protractors that were not shown against the bench needed to be supported so that the zero on the protractor was correctly aligned. Some candidates used trigonometry; in this case the method of determining the distances accurately needed to be shown clearly.

Credit was available for determining the mass of the oil. It was expected that candidates would identify a measuring instrument to measure mass, and clearly explain that the mass of the empty cylinder would be subtracted from the mass of the oil and cylinder to determine the mass of oil. A few candidates confused mass and weight.

To determine the constant *a*, the diameter of the cylinder needed to be measured; credit was awarded to most candidates for stating an appropriate measuring instrument. Some candidates were awarded credit for the additional detail that they would measure *d* in different directions and determine the mean. There was also further credit for explaining how the density of the oil could be determined. Candidates needed to state how the volume of the oil could be determined and then state an appropriate equation.

Two marks are available for the analysis of data. The majority of the candidates chose appropriate axes for a graph. The second mark was for correctly identifying how the two constants *a* and *b* could be determined; *a* needed to be the subject of the formula for this mark to be scored. There was also an additional detail mark for explaining how the graph showed that the relationship was valid. A significant number of candidates stated that a straight line through the origin would prove the relationship without realising that there should be a *y*-intercept.

Credit was available for describing an appropriate safety precaution. Candidates should be encouraged to give clearly reasoned safety precautions that are relevant to the experiment; candidates were expected to describe a safety precaution relating to the preventing oil spilling or preventing the glass cylinder breaking. A solution of using a plastic cylinder did not gain credit since it was changing the experiment.

Candidates should be encouraged to write their plans including appropriate detail; often candidates' answers suggested that they did not have sufficient practical experience. Vague responses were not credited. Those candidates who have followed a 'hands on' practical course are generally much better placed to gain credit for additional detail. It is essential that candidates' give detail relevant to the experiment in question rather than general 'textbook' rules for working in a laboratory.

Question 2

In this data analysis question, candidates were required to analyse data given for the current in different lengths of nichrome wire. Most candidates produced a correct table of results, correct graphical plots and well-drawn straight lines. Calculation of the gradient was generally good. The treatment of uncertainties is improving.

(a) This question was generally answered well.

(b) Most candidates correctly included the column heading. A number of candidates lost credit for rounding errors. It is expected that the number of significant figures in calculated quantities should be the same as, or one more than, the number of significant figures in the raw data; in this case I was given to two significant figures so it was expected that $1/I$ would be given to two or three significant figures. Some candidates did not work out the absolute uncertainties in $1/I$ correctly.

(c) (i) Candidates should be advised to ensure that the sizes of the plotted points are small. It is not possible to award credit for large 'blobs'. Candidates should be encouraged to check plots that do not appear to follow the line of best fit. A small number of candidates did not construct the error bars accurately.

(ii) Some candidates were careless in their drawing of the lines; candidates should be encouraged to use a transparent 30 cm ruler. Candidates should be encouraged to ensure that there is a balance of points on each side of the line. The worst acceptable straight line should be either the steepest possible line or the shallowest possible line that passes through all the error bars of all the data points used for the line of best fit. The majority of the candidates labelled clearly the lines on their graph; lines not indicated may be penalised in the future. A number of candidates were not credited for their lines since they were not straight. The worst acceptable line was not drawn accurately enough by a significant number of candidates.

(iii) This part was generally answered well. Most candidates clearly demonstrated the points they had used to determine the gradient. Some candidates did not use a sufficiently large triangle for their gradient calculation. A large number of stronger candidates clearly indicated the points that they used from the line of best fit. Some candidates used points from the table but did not gain credit because they did not lie on the line of best fit.

To determine the uncertainty in the gradient, candidates were expected to find the difference between the gradient of the line of best fit and the gradient of the worst acceptable line. Again stronger candidates clearly indicated the points that they used from the worst acceptable line. Some candidates were confused by which line was the best and which was the worst.

(iv) This part was also generally answered well. Most candidates clearly demonstrated the method they had used to determine the *y*-intercept. To determine the uncertainty in the *y*-intercept, candidates were expected to find the difference between the *y*-intercept of the line of best fit and the *y*-intercept of the worst acceptable line. Some candidates incorrectly used the same point for both calculations. For credit clear working was needed.

(d) (i) Candidates needed to determine a value for ρ using the gradient and a value for E using the *y*-intercept. Some candidates were confused by the powers. Other candidates were unable to write down appropriate units or gave their answers to too many significant figures.

(ii) For this part it is essential that candidates show their working. Generally the question was answered well, particularly by candidates who used the percentage uncertainties in gradient, E and d. Those candidates who attempted to calculate a maximum or minimum value for ρ tended to make more mistakes by using the incorrect combination of maximum and minimum values.

PHYSICS

Paper 9702/52
Planning, Analysis and Evaluation

Key Messages

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

General Comments

All candidates completed the paper and there was no evidence of time constraints. The majority of the scripts were clearly written. In general, graphs were well drawn with points and error bars easily identifiable. There was improvement in the presentation of mathematical working. Some candidates find the appropriate use of significant figures difficult. Skills required for describing experiments are best learnt from 'hands on' experience. In **Question 2** the treatment of uncertainties is not always fully understood.

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

Comments on Specific Questions

Question 1

Candidates were required to design a laboratory experiment to investigate how the angle ϕ at which a cylinder topples varies with the mass m of oil in the cylinder. Candidates were also required to verify the given equation and explain how the constants a and b could be determined from the measurements. In general the description of the experiment by candidates has improved. Some candidates stated that they would change the angle and measure the corresponding mass of oil.

Most candidates correctly identified the independent and dependent variables. Many candidates scored further credit for stating that the diameter of the cylinder needed to be kept constant. Fewer candidates considered that the temperature of the oil needed to be kept constant.

Five marks are available for the methods of data collection. Credit was awarded for a clearly labelled diagram. Diagrams should include the necessary pieces of apparatus set up as they would be used in the experiment. In this case a labelled protractor needed to be correctly positioned as the cylinder was about to topple. Protractors that were not shown against the bench needed to be supported so that the zero on the protractor was correctly aligned. Some candidates used trigonometry; in this case the method of determining the distances accurately needed to be shown clearly.

Credit was available for determining the mass of the oil. It was expected that candidates would identify a measuring instrument to measure mass, and clearly explain that the mass of the empty cylinder would be subtracted from the mass of the oil and cylinder to determine the mass of oil. A few candidates confused mass and weight.

To determine the constant *a*, the diameter of the cylinder needed to be measured; credit was awarded to most candidates for stating an appropriate measuring instrument. Some candidates were awarded credit for the additional detail that they would measure *d* in different directions and determine the mean. There was also further credit for explaining how the density of the oil could be determined. Candidates needed to state how the volume of the oil could be determined and then state an appropriate equation.

Two marks are available for the analysis of data. The majority of the candidates chose appropriate axes for a graph. The second mark was for correctly identifying how the two constants *a* and *b* could be determined; *a* needed to be the subject of the formula for this mark to be scored. There was also an additional detail mark for explaining how the graph showed that the relationship was valid. A significant number of candidates stated that a straight line through the origin would prove the relationship without realising that there should be a *y*-intercept.

Credit was available for describing an appropriate safety precaution. Candidates should be encouraged to give clearly reasoned safety precautions that are relevant to the experiment; candidates were expected to describe a safety precaution relating to the preventing oil spilling or preventing the glass cylinder breaking. A solution of using a plastic cylinder did not gain credit since it was changing the experiment.

Candidates should be encouraged to write their plans including appropriate detail; often candidates' answers suggested that they did not have sufficient practical experience. Vague responses were not credited. Those candidates who have followed a 'hands on' practical course are generally much better placed to gain credit for additional detail. It is essential that candidates' give detail relevant to the experiment in question rather than general 'textbook' rules for working in a laboratory.

Question 2

In this data analysis question, candidates were required to analyse data given for the current in different lengths of nichrome wire. Most candidates produced a correct table of results, correct graphical plots and well-drawn straight lines. Calculation of the gradient was generally good. The treatment of uncertainties is improving.

(a) This question was generally answered well.

(b) Most candidates correctly included the column heading. A number of candidates lost credit for rounding errors. It is expected that the number of significant figures in calculated quantities should be the same as, or one more than, the number of significant figures in the raw data; in this case I was given to two significant figures so it was expected that $1/I$ would be given to two or three significant figures. Some candidates did not work out the absolute uncertainties in $1/I$ correctly.

(c) (i) Candidates should be advised to ensure that the sizes of the plotted points are small. It is not possible to award credit for large 'blobs'. Candidates should be encouraged to check plots that do not appear to follow the line of best fit. A small number of candidates did not construct the error bars accurately.

(ii) Some candidates were careless in their drawing of the lines; candidates should be encouraged to use a transparent 30 cm ruler. Candidates should be encouraged to ensure that there is a balance of points on each side of the line. The worst acceptable straight line should be either the steepest possible line or the shallowest possible line that passes through all the error bars of all the data points used for the line of best fit. The majority of the candidates labelled clearly the lines on their graph; lines not indicated may be penalised in the future. A number of candidates were not credited for their lines since they were not straight. The worst acceptable line was not drawn accurately enough by a significant number of candidates.

(iii) This part was generally answered well. Most candidates clearly demonstrated the points they had used to determine the gradient. Some candidates did not use a sufficiently large triangle for their gradient calculation. A large number of stronger candidates clearly indicated the points that they used from the line of best fit. Some candidates used points from the table but did not gain credit because they did not lie on the line of best fit.

To determine the uncertainty in the gradient, candidates were expected to find the difference between the gradient of the line of best fit and the gradient of the worst acceptable line. Again stronger candidates clearly indicated the points that they used from the worst acceptable line. Some candidates were confused by which line was the best and which was the worst.

(iv) This part was also generally answered well. Most candidates clearly demonstrated the method they had used to determine the *y*-intercept. To determine the uncertainty in the *y*-intercept, candidates were expected to find the difference between the *y*-intercept of the line of best fit and the *y*-intercept of the worst acceptable line. Some candidates incorrectly used the same point for both calculations. For credit clear working was needed.

(d) (i) Candidates needed to determine a value for ρ using the gradient and a value for E using the *y*-intercept. Some candidates were confused by the powers. Other candidates were unable to write down appropriate units or gave their answers to too many significant figures.

(ii) For this part it is essential that candidates show their working. Generally the question was answered well, particularly by candidates who used the percentage uncertainties in gradient, E and d. Those candidates who attempted to calculate a maximum or minimum value for ρ tended to make more mistakes by using the incorrect combination of maximum and minimum values.

PHYSICS

Paper 9702/53
Planning, Analysis and Evaluation

Key Messages

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

General Comments

All candidates completed the paper and there was no evidence of time constraints. The majority of the scripts were clearly written. In general, graphs were well drawn with points and error bars easily identifiable. There was improvement in the presentation of mathematical working. Some candidates find the appropriate use of significant figures difficult. Skills required for describing experiments are best learnt from 'hands on' experience. In **Question 2** the treatment of uncertainties is not always fully understood.

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

Comments on Specific Questions

Question 1

Candidates were required to design a laboratory experiment to investigate how the electrical energy *E* supplied to a heater in water for a particular temperature change varied with the mass *m* of metal blocks in the water. Candidates were also required to verify the given equation and explain how the constants *a* and *b* could be determined from the measurements. In general the description of the experiment by candidates has improved. A significant number of candidates did not read the question carefully so answered in terms of specific heat capacity of the metal. Some weaker candidates stated that they would change the energy to the system and measure the corresponding change in mass of the blocks.

Most candidates could identify the independent and dependent variables and a significant number stated that the mass/volume of water needed to be kept constant. Many candidates did not state that the change in temperature of the water needed to be kept constant. A significant number of candidates wrote 'control' instead of 'constant' for the constant variable and this is not awarded credit.

Credit was available for a clearly labelled diagram and circuit. Diagrams should be realistic, well labelled, and have correct workable electrical circuits. Diagrams should include the necessary pieces of apparatus set up as they would be used in the experiment. A labelled thermometer with its bulb in the water was required. Several candidates did not include appropriate measuring instruments to enable the power/energy of the heater to be calculated. A common mistake was to include a variable resistor in the circuit with a voltmeter placed to measure the potential difference across both the heater and the variable resistor.

Determining the change in temperature requires measurement, by a thermometer, of the initial and final temperatures and the subtraction of their values. Very few candidates obtained credit for stating this.

Almost all candidates obtained credit for describing an appropriate instrument to determine the mass of the metal blocks. A few candidates confused mass and weight.

Credit was available for the analysis of data. The majority of the candidates were able to choose appropriate axes for a graph. The statement "plot a graph of $E = am + b$" is not acceptable. Some candidates gained credit for suggesting that a graph of *m* against *E* could be plotted; to gain further credit, candidates needed to indicate how the constants *a* and *b* could be determined from the graph that they had suggested. A significant number of candidates stated that a straight line through the origin would prove the relationship without realising that there should be a *y*-intercept.

Candidates should be encouraged to give clearly reasoned safety precautions that are relevant to the experiment; they were expected to describe a safety precaution relating to the use of a relevant safety item (e.g. gloves, tongs) and the reason for its use (touching/carrying a hot named piece of apparatus).

Candidates should be encouraged to write their plans including appropriate detail; often candidates' answers suggested that they did not have sufficient practical experience. Vague responses were not credited. Those candidates who have followed a 'hands on' practical course are generally much better placed to gain credit for additional detail. It is essential that candidates' give detail relevant to the experiment in question rather than general 'textbook' rules for working in a laboratory.

Question 2

In this data analysis question, candidates were required to plot a graph v^2 against *r* where *v* is the speed of the mass *m* rotating in a horizontal circle of radius *r*. Most candidates produced a correct table of results, correct graphical plots and well-drawn straight lines. Calculation of the gradient was generally good. The treatment of uncertainties is improving.

(a) This question was generally answered well.

(b) Most candidates correctly included the column headings. A number of candidates lost credit for rounding errors. It is expected that the number of significant figures in calculated quantities should be the same as, or one more than, the number of significant figures in the raw data; in this case *t* was given to two significant figures so it was expected that v^2 would be given to two or three significant figures. Some candidates did not work out the absolute uncertainties in v^2 correctly.

(c) (i) Candidates should be advised to ensure that the sizes of the plotted points are small. It is not possible to award credit for large 'blobs'. Candidates should be encouraged to check plots that do not appear to follow the line of best fit. A small number of candidates did not construct the error bars accurately.

(ii) Some candidates were careless in their drawing of the lines; candidates should be encouraged to use a transparent 30 cm ruler. Candidates should be encouraged to ensure that there is a balance of points on each side of the line. The worst acceptable straight line should be either the steepest possible line or the shallowest possible line that passes through all the error bars of all the data points used for the line of best fit. The majority of the candidates labelled clearly the lines on their graph; lines not indicated may be penalised in the future. A number of candidates were not credited for their lines since they were not straight. The worst acceptable line was not drawn accurately enough by a significant number of candidates.

(iii) This part was generally answered well. Most candidates clearly demonstrated the points they had used to determine the gradient. Some candidates did not use a sufficiently large triangle for their gradient calculation. A large number of stronger candidates clearly indicated the points that they used from the line of best fit. Some candidates used points from the table but did not gain credit because they did not lie on the line of best fit.

To determine the uncertainty in the gradient, candidates were expected to find the difference between the gradient of the line of best fit and the gradient of the worst acceptable line. Again stronger candidates clearly indicated the points that they used from the worst acceptable line. Some candidates were confused by which line was the best and which was the worst.

(d) (i) Candidates needed to determine a value for *P* using the gradient. This was generally answered well, although a small number of candidates did not use the gradient. For full credit the correct unit was needed, and this was omitted by some candidates.

(ii) For this part it is essential that candidates show their working. Generally the question was answered well, particularly by candidates who used the method of adding percentage uncertainties in gradient and mass. Those candidates who attempted to calculate a maximum or minimum value for *P* tended to make more mistakes by using the incorrect combination of maximum and minimum values.

(e) (i) Most candidates were able to calculate a value of *v* which was in the appropriate range. Other candidates did not state the answer to 2 or 3 significant figures.

(ii) Some candidates did not show detailed working for calculating the percentage uncertainty in *v*. Candidates must make clear how the answer is achieved. Ideally, the working will show the formula used, the correct data substituted in the formula, and the answer rounded to an appropriate number of significant figures. A number of candidates did not know how to allow for the square root. A significant number of candidates assumed incorrectly that the percentage uncertainty in the gradient was equal to the percentage uncertainty in *P*.

Candidates who approach this type of question by determining a maximum or minimum value of *v* need to take care to use the appropriate combination of maximum and minimum values in their working.