PHYSICS

Paper 9702/11
Multiple Choice

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

General comments

It is advisable to read through each question in its entirety before looking at the four possible answers. When answering numerical questions, candidates should take particular care with prefixes and powers-of-ten, and it is a good idea to double-check any calculations performed on a calculator. The spaces on the question paper should be used to carry out the calculations and any other necessary working such as rearranging equations.

Questions involving graphs need careful attention, taking note of which quantities are plotted on which axes, as these may differ from the 'standard' graphs in some textbooks.

Candidates found **Questions 5**, **9**, **23** and **33** difficult. They found **Questions 1**, **3**, **8**, **13**, **17**, **31** and **39** relatively straightforward.

Comments on specific questions

Question 5

The majority of candidates recognised that, as the car tyres wear, the rate of rotation of the tyres must **increase** for the car to travel at the same speed, and this would mean the speed displayed by the car's speedometer (which is proportional to the rate of rotation of the tyres) would increase, i.e. be greater than the true speed of the car.

When calculating the percentage error in the speedometer reading, many candidates used a value of 6 mm rather than 12 mm for the change in diameter of the tyres, obtaining a value of 1% for the error in the speedometer reading (answer **A**) rather than the correct answer of 2% (answer **B**).

Question 7

A significant number of candidates chose **A** or **B** rather than the correct answer **D**. As air resistance is negligible, there are no forces acting horizontally on the stone. This means that the horizontal component of velocity of the stone remains constant, so the only possible graph is **D**.

Question 9

Over half the candidates chose answer **C** rather than the correct answer **B**. If the object in **C** is in equilibrium, the two forces shown are equal and opposite, but these are not the forces referred to in Newton's third law of motion. In applying Newton's third law, two key points need to be remembered:

- the two forces act on **different** objects
- the two forces are of the same **type** (e.g. gravitational).

In **C**, both forces act on the same object; one is gravitational (the object's weight) while the other is electrical (the repulsive force between atoms 'pushing up' the object).

In **D**, the two forces act on different objects (the Earth and the Moon) and are of the same type (gravitational), so these are the forces described by Newton's third law.

Question 10

The majority of candidates answered this question correctly, but many weaker candidates chose **B** rather than **C**. A smaller mass, with the same dimensions as the original mass, will have the same resistive force F acting on it at any given speed v. The net force acting on the mass, $mg - F$, will be smaller for the second stone as m is smaller. It will accelerate more slowly towards the Earth, falling a smaller distance than the original stone in any given time (graph **C**).

Question 11

Many candidates chose answer **A** rather than the correct answer **D**. As the helium atom has a perfectly elastic collision with the wall, the total kinetic energy is conserved and the atom rebounds with the same speed v. As momentum is a vector quantity, the momentum of the atom has changed from $+mv$ to $-mv$, a total change of $2mv$.

Question 12

The incorrect answer **D** was commonly chosen. The weight of the iceberg is $\rho_I gAH$ where A is the cross-sectional area of the iceberg. The pressure at a depth $(H - h)$ below the surface of the water is $\rho_W g(H - h)$, so the upthrust from the water on the bottom of the iceberg is $\rho_W gA(H - h)$. Equating the two forces and rearranging leads to the answer **A**.

Question 22

Most candidates recognised that the correct graph must be **A** or **B** as the displacement of the particle must vary between positive and negative values. The wavelength of the wave is 4.0 cm and the speed is 20.0 cm s^{-1}. The frequency of the wave is therefore v / λ = 5.0 Hz and the time for one complete oscillation is 1 / 5.0 Hz = 0.20 s, making **A** correct.

Question 23

Many candidates found this question difficult, with the majority selecting **C** rather than the correct answer **A**. The simplest way to answer this question is to draw (on the question paper) the position of the wave a short time after the position shown in the question. From this, it is clear that both points **B** and **D** move only a small distance compared with **A** and **C** in the same short time interval. Comparing **A** and **C**, it is also clear that **C** moves downwards whilst **A** moves upwards.

Question 25

Most candidates recognised that this was an example of the Doppler effect, with the frequency of the waves at X increasing as the source of the waves (the insect) moves towards X. The speed of the waves is independent of the speed of the source of the waves.

Question 27

The majority of candidates answered this question correctly (answer **D**). Most of the other candidates equated the wavelength with the distance between adjacent nodes, rather than half the wavelength.

Question 32

The majority of candidates answered this question correctly. Answer **D** is correct as all the other answers are multiples of 1.6×10^{-19} C. Some weaker candidates chose answer **A**, perhaps because it is the only negatively charged ion.

Question 33

Many candidates found this question difficult, selecting **A** rather than **B**. In the question, point P is at a higher potential than point Q (as indicated by the + and – signs). This means that work needs to be done to move a positive charge from Q to P (the positive charge is repelled by point P so has to be 'pushed' towards it). As 1 V is 1 J C^{-1}, the energy needed to transfer +1 C from Q to P is 1 J.

Question 34

Most candidates chose either answer **A** or **B**, with approximately equal numbers of candidates choosing either answer. It is important to note that the graphs show current I on the *x*-axis and potential difference V on the *y*-axis. For a filament lamp, doubling the p.d. will increase the current in the lamp, but by less than double. The correct graph is **B**.

PHYSICS

Paper 9702/12
Multiple Choice

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

General comments

It is advisable to read through each question in its entirety before looking at the four possible answers. When answering numerical questions, candidates should take particular care with prefixes and powers-of-ten, and it is a good idea to double-check any calculations performed on a calculator. The spaces on the question paper should be used to carry out the calculations and any other necessary working such as rearranging equations.

Questions involving graphs need careful attention, taking note of which quantities are plotted on which axes, as these may differ from the 'standard' graphs in some textbooks.

Candidates found **Questions 16**, **18**, **24** and **33** difficult. They found **Questions 3**, **6**, **15**, **17**, **27**, **36** and **40** relatively straightforward.

Comments on specific questions

Question 5

In order to answer this question, candidates needed to recall that density = mass / volume. The percentage uncertainty in the mass is 1.0% and the percentage uncertainty in the diameter is 0.9%. Some candidates just added the two uncertainties together (1.9%) or added twice the uncertainty in the diameter to the uncertainty in the mass (2.8%). As the volume is proportional to the **cube** of the diameter, the total percentage uncertainty in the density is $1.0\% + 3 \times 0.9\% = 3.7\%$ (answer **D**).

Question 8

The majority of candidates chose the correct answer to this question (answer **B**). The key feature of the graph is the sudden change in the value of the quantity being plotted from zero to a large (negative) value. The changes in the acceleration of a firework, the speed of a javelin or the speed of a high jump athlete are all gradual; the only sudden changes occur when they hit the ground and the value of the quantity becomes zero.

Question 10

The majority of candidates answered this question correctly, but many weaker candidates chose answer **B** rather than answer **A**.

If the constant resistive force is R then:

$F - R = ma$

and

$2F - R = 3ma$.

Solving these two equations gives $R = ma$.

Question 14

Most candidates answered this question correctly. As the car is travelling at constant speed up the slope, the total force acting up the slope (produced by the car's engine) must equal the total force acting down the slope. Some candidates confused $\sin\theta$ with $\cos\theta$ when calculating the component of the car's weight acting down the slope; others omitted the resistive force F from the total force acting down the slope.

Question 16

Many candidates found this question difficult. The question asks which statement is **not** correct. As the parachutist is falling at constant (terminal) velocity the kinetic energy of the parachutist is constant, so statement **B** is the incorrect statement. Several candidates chose **A** for their answer, but **A** is true – as the parachute descends it is constantly colliding with air molecules, giving them additional kinetic energy (the air becomes a little warmer).

Question 18

Candidates found this question difficult. The gravitational potential energy of the jumper is mgh, where h is the height above the lowest point reached. A graph of gravitational potential energy against vertical distance fallen must vary linearly from mgh at the top of the jump to zero at the lowest point, eliminating graphs **B** and **D**. As the elastic rope obeys Hooke's law, the elastic potential energy of the rope is $\frac{1}{2}kx^2$, where k is the spring constant of the rope and x the extension of the rope. From the moment the elastic rope becomes just taut, the elastic potential energy in the rope depends on x^2 when the bungee jumper descends an extra distance x – a non-linear relationship, so graph **A** is correct.

Question 19

The majority of candidates calculated the power of the engine correctly. Other candidates omitted to take into account the efficiency of the engine (40%).

Question 20

Almost half the candidates calculated the elastic potential energy in wire Y correctly. Others thought that doubling the diameter of the wire would halve the stress on the wire and so halve the extension of wire Y as the same force is applied to both wires. Doubling the diameter increases the cross-sectional area by a factor of 4, reducing the stress on the wire by the same factor. As the length of the wire and the force applied to the wire do not change, the extension of wire Y is ¼ of the extension of wire X. The gain in elastic potential energy ($\frac{1}{2}Fx$) of wire Y is then $0.25E$ (answer **A**).

Question 24

Many candidates found this question difficult. One way of approaching this question is to draw the position of the wave a short time after $t = 0$. At time $t = 0$ the displacement of point P is a non-zero positive value, so graphs **B** and **C** can be rejected. As the wave moves to the right, the point P initially moves upwards, i.e. the displacement of the point P increases, indicating that the correct graph is **D**.

Question 28

The majority of candidates answered this question correctly; others did not take into account the time-base setting being given in $\mu s\,mm^{-1}$ and the divisions on the screen of the CRO being shown in cm.

One complete cycle occurs in 3 cm (3 divisions) of the screen of the CRO, which is a time T of $30\,mm \times 5\,\mu s\,mm^{-1} = 150\,\mu s$. The frequency is $1/T = 1/(150 \times 10^{-6}) = 6.7 \times 10^3\,Hz$ (answer **C**).

Question 29

Most candidates correctly rejected diagram **A** as a possible answer as there is no central ('zero order') maximum. The angles of the other maxima are given by the equation $\theta = \sin^{-1}(n\lambda/d)$, where d is the slit spacing of the diffraction grating, λ is the wavelength of light and n is the order of the maximum.

Candidates needed to be able to recall that the angle of the second-order maximum (if there is one) is always a little more than twice the angle of the first-order maximum. Alternatively, substituting typical values into the equation will give a good idea of the relative positions of the different maxima. For example, if $\lambda/d = 0.4$, the maxima occur at angles of 0°, 23.5° and 53.1°, corresponding to $n = 0,1$ and 2. For this reason, **B** and **D** do not have the right angles, and **C** is the correct answer.

Question 31

The majority of the candidates answered this question correctly, though a significant number thought that decreasing the width of each slit would increase the distance on the screen between adjacent fringes. Decreasing the width will not affect the position of the maxima but will affect their brightness.

Question 33

Many candidates found this question difficult. As the different sections of the wire are 'in series' with each other, the current (the charge passing per unit time) must be the same at all points of the wire. If charge Q passes R in time t, charge Q will also pass point S in time t (answer **B**).

PHYSICS

Paper 9702/13
Multiple Choice

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

General comments

It is advisable to read through each question in its entirety before looking at the four possible answers. When answering numerical questions, candidates should take particular care with prefixes and powers-of-ten, and it is a good idea to double-check any calculations performed on a calculator. The spaces on the question paper should be used to carry out the calculations and any other necessary working such as rearranging equations.

Questions involving graphs need careful attention, taking note of which quantities are plotted on which axes, as these may differ from the 'standard' graphs in some textbooks.

Candidates found **Questions 11**, **17**, **28**, **30**, **36** and **39** difficult. They found **Questions 3**, **8**, **15**, **16**, **18**, **22** and **31** relatively straightforward.

Comments on specific questions

Question 1

Most candidates answered this question correctly, though a significant number of candidates thought that the gram was an SI base unit.

Question 6

Around half of the candidates calculated the percentage uncertainty in the volume of the sphere correctly. Others calculated the percentage uncertainty in the diameter of the sphere correctly, but did not then calculate three times this value as the percentage uncertainty in the volume of the sphere, not recognising that the volume of the sphere is proportional to the cube of the diameter.

Question 7

Almost all candidates calculated the acceleration of the object as $4.0\,\mathrm{m\,s^{-2}}$ (the gradient of the graph), though some miscalculated the displacement of the object (the area under the graph) after 5.0 s.

Question 9

Most candidates chose **C** or **D**. The diagram in **C** is not possible (and is therefore the correct answer) because the total momentum in the vertical direction is not conserved. The diagram shows both particles emerging from the collision with a component of momentum in the downwards direction; neither particle has any vertical momentum before the collision.

Question 10

The majority of candidates answered this question correctly, though a significant number of candidates incorrectly chose **A** or **D**. In the uniform electric field shown, the force on the positively charged particle is constant, so the acceleration of the charged particle must be constant.

Question 11

Candidates found this question difficult, with many selecting **B** or **D** rather than the correct answer **A**. If the weight of the picture is W, then resolving forces vertically gives $2T\cos\theta = W$.

Increasing the length of the cord will reduce the value of θ and so increase the value of $\cos\theta$, making the value of T smaller (the correct answer **A**). Moving points X and Y further apart will increase θ, decreasing the value of $\cos\theta$ and increasing the value of T, so **B** is incorrect. Moving points X and Y to the top edge of the picture, keeping their distance apart constant and the length of the cord constant, will have no effect on the tension. From the equation above, $W = 2T\cos\theta$, so statement **D** is incorrect.

Question 12

Most candidates chose either **B** or **C**. If the tension force in ZY is T, calculating moments about point X:

$T \times 0.50 \sin 30° = 75 \times 0.50$

$T = 75 / \sin 30°$.

If R is the horizontal force at X, then resolving horizontally:

$R = T\cos 30°$.

Combining these two equations gives:

$R = 75 / \tan 30° = 130\,\mathrm{N}$.

Question 17

Many candidates found it difficult to apply both conservation of momentum and energy laws correctly in order to answer this question.

Applying the law of conservation of total momentum to the collision of the lead pellet with the stationary clay block:

$5.0 \times 10^{-3} \times 200 = 100 \times 10^{-3} \times v$

$v = 10.0\,\text{m}\,\text{s}^{-1}$

where v is the velocity of the combined clay block and pellet immediately after the impact.

The height h reached by the clay block and pellet can then be obtained using the law of conservation of energy:

$mgh = \frac{1}{2}mv^2$

$h = v^2 / 2g$

This gives $h = 5.1\,\text{m}$ (answer **A**).

Question 19

Many candidates answered this question correctly. Those who were not correct either omitted to convert the contraction of the rods from mm to m, or converted mm^2 to m^2 incorrectly, or did not take account of the presence of **four** rods supporting the object.

Question 23

Many candidates chose **C** for the time-base setting rather than the correct answer **B**. The frequency of the sound wave is 270 Hz so the period of the sound wave is $1/270 = 3.70 \times 10^{-3}\,\text{s}$. (Almost) 2.5 waves are displayed on the screen of the CRO, so the time taken for the electron beam to travel across the screen is $2.5 \times 3.70 \times 10^{-3} = 9.3 \times 10^{-3}\,\text{s}$. As the screen is 9 cm across:

time-base = $(9.3 \times 10^{-3}\,\text{s}) / (9\,\text{cm}) = 1.0 \times 10^{-3}\,\text{s}\,\text{cm}^{-1}$.

Question 28

Many candidates found this question difficult, choosing **A** rather than the correct answer **D**. If light waves from the two sources R and S are emitted 180° out of phase and the path difference is $\frac{1}{2}\lambda$, the waves will arrive in phase at P, interfere constructively and produce a point of maximum light intensity, so **A** is not correct.

Question 30

Candidates found this question difficult, either only counting the number of maxima on one side of the screen, or omitting to include the central 'zero order' maximum in their calculations. Almost equal numbers of candidates chose each of the four answers.

From the diffraction grating equation, a maximum occurs at an angle θ, where $\sin\theta = n\lambda / d$ when d is the slit spacing of the diffraction grating, λ is the wavelength of the light and n is the order of the maximum. Since $\sin\theta$ must be less than 1, $n < d / \lambda$. Substituting values gives $n < 4.8$.

As n is an integer, it can have values 0, 1, 2, 3 and 4. There is a central 'zero order' maximum in the centre of the screen ($n = 0$) together with four maxima either side of the central maximum, making a total of 9 maxima that could be observed on the screen.

Question 34

A significant number of candidates chose **B**. If X_1 is connected to Y_1, point Z_1 (which is connected to the supply) is not connected to any wire so there cannot be a complete circuit.

Question 36

Candidates found this question difficult.

If the current in the first circuit is I, the e.m.f. of the cell is V and the resistance of the lamp is R, then $I = V / R$.

In the second circuit, there is a current of I_1 in the left-hand cell/lamp and a current of I_3 in the right-hand cell/lamp. Using Kirchhoff's second law separately on the two loops of the circuit:

$V = I_1R + (I_1 - I_3)R$ (left-hand loop)

$V = (I_3 - I_1)R + I_3R$ (right-hand loop).

Combining these equations shows that $I_1 = I_3 = V / R$ (= I). The net current in lamp 2 is ($I_1 - I_3$) which is zero, so lamp 2 does not light. The current in lamps 1 and 3 has not changed, so both light normally (answer **C**).

Question 39

Candidates found this question difficult. They should be able to recall that the diameter of a typical atomic nucleus is of the order of 10^{-14} m. The diameter of a typical atom is of the order of 10^{-10} m and the diameter of the nucleus is a few orders of magnitude smaller. The incorrect answer **C** was popular.

Question 40

Most candidates recognised that an electron is emitted in β^- decay (rather than a positron) and the majority gave the correct answer **A**. Those that did not often thought that an up quark changes into a down quark in β^- decay, rather than a down quark changing into an up quark.

PHYSICS

Paper 9702/21
AS Level Structured Questions

Key messages

- Candidates should be able to recall precisely the laws and definitions that are referred to in the syllabus learning outcomes. A wrong or omitted key word can lead to marks not being awarded if it is an important part of a definition.
- Candidates should ensure that they do not prematurely 'round off' any intermediate answers in a numerical calculation as this can lead to an inaccurate final answer.
- In 'show that' questions, candidates should methodically present every step of their calculation as well as the final answer.
- In general, a final answer to a numerical calculation should be expressed as a decimal number and not left as a fraction.

General comments

The less able candidates had opportunities to gain credit in questions where standard definitions and substitution of given values into basic equations were required, for example in **Questions 1(a)**, **1(b)** and **2(a)**. There was also the use of basic knowledge and understanding to determine quantities or explain phenomena, for example in **Questions 4(b)(i)**, **6(b)**, **6(d)(i)** and in **Questions 6(a)** and **7(a)**. A significant number of candidates were able to complete these more straightforward questions.

The questions had more challenging parts where the application of knowledge and understanding was more demanding. Examples were the determination of the uncertainty in **Question 1(b)(ii)**, the showing of the momentum changes in **Question 2(d)**, the determination of the volume of a sphere in **Question 4(a)** and the determination of the kinetic energy and speed using energy transfer in **Question 3(b)**. **Question 4** required more detailed knowledge and understanding of the movement of charge due to forces in an electric field. The latter parts of **Questions 5**, **6** and **7** all had more demanding elements. Only the more able candidates completed these types of question.

Comments on specific questions

Question 1

(a) The majority of candidates gave the definition of velocity. A small number referred to distance rather than displacement or the speed of an object in a particular direction.

(b) (i) The calculation was completed correctly by the majority of candidates. A very small number incorrectly manipulated the equation or did not square the velocity.

(ii) A significant number of candidates calculated the correct percentage uncertainty and absolute uncertainty. Only the strongest candidates gave the value of *k* to the correct number of significant figures and the absolute uncertainty to one significant figure. There was a large minority who did not demonstrate a clear understanding of the meaning of percentage uncertainties. Many of these candidates confused fractional and percentage uncertainties. Some candidates attempted to determine fractional uncertainties by combining the values of the quantities and their percentage uncertainties using a variety of incorrect methods. A common misconception was to determine the fractional uncertainty by calculating, for example, the density using 0.04 / 1.29.

Question 2

(a) The majority of candidates gave the correct definition for momentum. A minority of gave an answer in terms of conservation of momentum which was not applicable here.

(b) (i) The majority of candidates gave the correct time interval. There were a significant number who gave the time at the start of the collision and not the time interval for the collision.

(ii) 1. The momentum and hence the velocity were increasing at a constant rate. Weaker candidates often wrongly stated that the acceleration was increasing.

2. The majority of candidates gave the correct answer.

(c) The majority of candidates were awarded credit for the correct relationship between the force and the rate of change of momentum. Further credit was obtained by stronger candidates who calculated the force on block Y by determining the gradient of the graph line during the change in momentum of block Y. A significant number of candidates used *force* = *momentum* / *time* instead of *force* = *change in momentum* / *time* and divided 0.4 by 40×10^{-3}. Less able candidates attempted to calculate the area under the graph instead of the gradient. Power-of-ten errors in the value of the time were seen frequently.

(d) The majority of candidates showed the momentum of block X to be constant until the collision with block Y. The correct change in momentum of block X during the collision was indicated by only the strongest candidates. A significant number showed the momentum of block X to be constant after the collision for the correct time interval.

Question 3

(a) (i) The majority of candidates showed the increase in elastic potential energy using the area under the graph. A significant number also used $\frac{1}{2}kx^2$. For the latter method, the answer obtained depended on the values used from the graph to calculate k. Many used a small range for the change in the force or chose points that were difficult to read, and then obtained an inaccurate value for k. A small number of weak candidates tried to equate the change in gravitational potential energy with the gain in elastic potential energy.

(ii) The majority of candidates obtained the correct answer. The weaker candidates tended to start with the correct expression for the gravitational potential energy but made errors in the substitution of the values of the terms. A common mistake was to use the weight as the mass. Sometimes the mass was calculated from the weight and then multiplied by the acceleration of free fall. This often led to inaccuracies due to premature rounding of intermediate answers. The full distance from the block to the fixed point at the top of the spring was sometimes used as the change in height.

(b) (i) The correct energy transfer was calculated by stronger candidates. A significant number of candidates equated the kinetic energy with the decrease in gravitational potential energy. Other candidates added the gravitational potential energy to the elastic potential energy to give the kinetic energy.

(ii) The symbol expression for kinetic energy was correctly used by the majority of candidates to determine the speed of the block. A significant number of candidates used the weight for the mass of the block.

Question 4

(a) (i) The majority of the candidates gave the expression for density and showed the calculation of the volume of the sphere. The full substitution of values needed to be seen in the working as this was a 'show that' question. The weaker candidates were unable to show the calculation of the volume of a sphere.

There were many answers which had been set out poorly, with all the working on a single line with the answer from one calculation running into the next. These answers are often so unclear that it is impossible to award credit. Candidates should be encouraged to lay out their working as clearly as possible.

(ii) The stronger candidates explained their answer in terms of the quantisation of charge. The weaker candidates attempted to compare the size of the charge with the mass of the drop, often suggesting that the charge was too large for the mass. The powers of ten for the charges may have been incorrectly interpreted by these candidates.

(b) (i) The majority of candidates gave the correct answer. A minority of candidates could not recall the appropriate expression for the electric field strength or made a power-of-ten error.

(ii) The correct answer was given by the stronger candidates. The explanation given by the weaker candidates was often incomplete, with the drop said to be travelling at constant speed or with no acceleration but without reference to force. The condition for equilibrium of no resultant force was also required to complete the explanation. Some candidates suggested that the force was zero rather than that the *resultant* force was zero. Some did not read the question carefully and suggested that the drop was stationary and that this was the reason for it being in equilibrium.

(iii) The stronger candidates equated the electric force with the weight to determine the charge on the drop. The weaker candidates equated the electric force to the product of mass and acceleration, and had no value for the acceleration or thought that the acceleration was zero. The majority of the candidates gave the sign of the charge as positive, presumably because the drop was moving towards the negative plate. The fact that the electric force was directed upwards to produce the equilibrium condition was missed by the majority of candidates.

(c) (i) A significant number of the stronger candidates started with the electric force being reduced because of the decrease in the potential difference. Very few candidates went on to explain that the resultant force was now downwards. The majority did not compare the magnitudes of the forces acting on the drop or they inappropriately compared the weight with the electric field strength. Many thought the charge on the drop would be reduced by the reduction in the potential difference between the plates.

(ii) A significant number of candidates were able to describe the change in the field pattern. There was a large number of candidates that gave no response.

(d) (i) There were very few correct answers. A significant number gave weight or gravitational force as a force that cannot act on an oil drop in a vacuum. There were many answers that seemed to be given as a result of the question not being read carefully.

(ii) The majority of answers were correct.

Question 5

(a) (i) There were very few correct answers. Only the strongest candidates were able to give the correct expressions. There were many attempts by less strong candidates to give expressions that could still lead to the required equation in **(ii)**. The majority of these expressions were incorrect.

(ii) The majority were not able to deduce the equation because their answers in **(i)** were incorrect. A significant number of candidates were unsuccessful because they stated the final equation but without any reference to the answers in **(i)**.

(b) A significant number of candidates were unable to convert the distance on the screen (in units of cm) corresponding to one cycle of the waveform to the time period in units of ms. Some of the candidates made a power-of-ten error by not converting the units of ms to s.

(c) (i) There was a significant number of candidates who gave the correct answer. A considerable number gave incorrect statements such as the waves have the 'same phase difference' or the waves are 'in phase'.

(ii) The strong candidates gave the correct answer. There were many incorrect values with 90° and 360° being the most common. There was a significant number that gave no response.

(iii) Very few candidates realised that the path difference for the waves that travelled from the two sources to Y was 2λ. The majority of candidates were unable to use the basic principles for the production of a minimum when two waves overlap. Many attempted to use inappropriate geometry calculations or the equations applicable to Young's double slits or the diffraction grating. There was a very large number that gave no response.

Question 6

(a) A minority of the candidates explained the difference as being due to the energy dissipated in the internal resistance. Many candidates did not follow the instruction in the question to explain the difference in terms of energy. These candidates described the difference as being due to 'lost volts' or by comparing the energy transfer for the e.m.f. and potential difference.

(b) The majority of the candidates gave the correct answer. There were many answers given in terms of symbols not given in the question or equations that were not homogeneous.

(c) (i) The majority of candidates explained that the e.m.f. was the value of the potential difference when the current was zero. A number of candidates spoiled their answer by suggesting that this was when the resistance *R* or *r* was zero. Some candidates merely repeated the question and said that the e.m.f. was 2.8 V when the current was zero, without relating the voltage value when the current was zero to the given value for the e.m.f. Some answers referred to the graph but did not contain the necessary detail, such as 'the point where the graph starts from' instead of the *y*-intercept.

(ii) A significant number of candidates were able to use the equation given in **(b)** or the gradient of the graph to then determine the internal resistance.

(d) (i) The majority of candidates determined the current from the graph when the potential difference was 2.1 V and then obtained the correct value for resistance *R*.

(ii) A small minority of candidates were able to use the current from **(d)(i)** to calculate the correct final answer. There was a very large number that gave no response.

(iii) Only the very able candidates were able to calculate the correct time taken. The majority were able to give an equation relating the energy used to the potential difference, current and time. The battery had to supply energy to both the internal and external resistances during this time and therefore the e.m.f. and not the terminal potential difference should have been used in the calculation. Some candidates used the final energy in the battery as the energy used. A significant number of candidates gave no response.

Question 7

(a) A minority of candidates gave an acceptable answer. The stronger candidates described a positively charged nucleus or stated that the majority of the mass of the atom was in the nucleus. Many of these candidates described the mass or charge to be in the centre region rather than referring to the nucleus. The weaker candidates gave insufficient detail or incorrect descriptions such as 'all of the charge on the atom is in the centre'. A large number of candidates gave no response.

(b) (i) The correct charge was given by a minority of candidates.

(ii) The correct flavour of quark was determined by the stronger candidates. A significant number only gave an answer without explaining their working and this could not be given credit. Some candidates gave the quark composition for protons and neutrons without any reference to the question. The hadron in the question involved a strange quark but this was omitted or ignored by many candidates. Again many weaker candidates gave no response.

PHYSICS

Paper 9702/22
AS Level Structured Questions

Key messages

- Candidates should be able to recall precisely the laws and definitions that are referred to in the syllabus learning outcomes. A wrong or omitted key word can lead to marks not being awarded if it is an important part of a definition.
- Candidates should ensure that they do not prematurely 'round off' any intermediate answers in a numerical calculation as this can lead to an inaccurate final answer.
- In 'show that' questions, candidates should methodically present every step of their calculation as well as the final answer.
- In general, a final answer to a numerical calculation should be expressed as a decimal number and not left as a fraction.

General comments

In general, the candidates had a good understanding of what was required by each question part.

There were many opportunities for the weaker candidates to show their understanding in straightforward questions, such as in **Questions 1(b)(i)**, **3(b)(i)**, **3(c)** and **5(b)(i)**. Weaker candidates often found it difficult to apply their knowledge and understanding to more challenging questions. For example, they found it difficult to apply their knowledge and understanding of forces and moments to **Questions 3(b)(ii)**, **(iii)** and **(iv)**, and they found it difficult to calculate the acceleration of charged particles in an electric field in **Question 6(c)(i)**.

There was no evidence of candidates lacking time to complete the paper.

Comments on specific questions

Question 1

(a) The absolute uncertainty in the measurement of the diameter was usually calculated correctly.

(b) (i) The majority of the candidates were able to correctly calculate the pressure. The most common mistake was to forget to square the value of the diameter.

(ii) Most answers were correct. The most common mistake was not doubling the percentage uncertainty of the diameter during the calculation. The weakest candidates sometimes confused absolute uncertainty with percentage uncertainty and so tried to find the final answer simply by adding the absolute uncertainties of the measurements.

Question 2

(a) Some candidates stated Newton's second law of motion in terms of the relationship between resultant force, mass and acceleration. This is a special case of the second law and is not the complete statement. Other candidates wrongly referred to 'change of momentum' instead of 'rate of change of momentum' in their statement of the law.

(b) (i) Most candidates realised that the distance travelled could be determined from the area under the velocity–time graph. Some candidates did not realise the significance of the scale on the velocity axis starting at $8\,\text{m}\,\text{s}^{-1}$, rather than at zero, which gives a 'false' origin. This meant that they only calculated the area under the graph that could be seen on the page, which is not equal to the true distance travelled. A small proportion of the candidates calculated the distance travelled by using an equation of uniform acceleration.

(ii) 1. The majority of the candidates calculated the correct acceleration.

2. This was a straightforward calculation that was usually answered correctly. A small number of the weakest candidates attempted to do a reverse calculation from the value of the force given in the next question part, which did not give the correct answer.

3. Most candidates realised that they needed to clearly present the numerical calculation as well as the final answer because this was a 'show that' question.

4. The useful output power of the engine could be calculated from the product of the force exerted by the engine and the instantaneous velocity of the car at time $t = 10\,\text{s}$. A common mistake was to use the resultant force of 340 N instead of the force exerted by the engine of 1300 N. Another common error was to use the average velocity of the car over the time interval of the first 10 s instead of the instantaneous velocity of the car at time $t = 10\,\text{s}$.

(c) Most candidates were able to accurately recall the relevant symbol equations for Young modulus, stress and strain. The weakest candidates sometimes incorrectly rearranged the equations or used the wrong value of the force.

(d) Although many answers were correct, a significant proportion of the candidates were unable to apply the Doppler effect formula given on the Formulae sheet. The most common error was to substitute the value of the velocity of the car with the wrong sign.

Question 3

(a) A common error was to state that the centre of gravity is the point where all the weight of a body actually acts, rather than where it is taken to act. It is incorrect to refer to 'mass' instead of 'weight'.

(b) (i) The majority of the answers were correct. The most common mistake was to calculate the horizontal component of the tension force instead of its vertical component.

(ii) Only the strongest candidates were able to explain that the force on the sign at B does not have a moment about point A because the line of action of the force has zero perpendicular distance from A. Many candidates found it difficult to articulate a sufficiently precise explanation. Weaker candidates sometimes vaguely stated that the force and point A were either parallel or perpendicular.

(iii) The candidates were asked to show that the weight of the sign is 150 N and therefore it was essential that they showed all the steps in their calculation in a clear logical sequence. Several methods of calculation were possible.

(iv) This part of the question challenged the majority of the candidates. The most common mistake was to add, instead of subtract, the weight and the vertical component of the tension in the wire.

(c) The majority of the answers were fully correct. It was expected that the final answer would be expressed as a decimal number, rather than being left as a fraction. The most common error was to unnecessarily subtract the height of the sign from the actual distance moved by the nut of 4.8 m.

Question 4

(a) (i) Most candidates found it difficult to state precisely what is meant by the displacement of a progressive water wave. The strongest candidates correctly stated that it was the distance in a specified direction of a point on the wave from the equilibrium position. Many candidates simply stated that it was the 'distance moved by the wave' which was too vague. The weakest candidates sometimes confused displacement with wavelength. Others did not read the question carefully and described general displacement rather than the displacement of a wave.

(ii) This part of the question was generally well answered.

(b) Most answers correctly stated that intensity was directly proportional to the square of the amplitude. However, most candidates were unable to apply this relationship to the question and often did not realise that the amplitude of the resultant wave was equal to the difference in the amplitudes of wave X and wave Y.

(c) (i) Successful answers described how the light waves spread as they pass through the slits in the grating. Candidates should refer to spreading and not bending of the waves because bending describes refraction. Many answers described the subsequent interference of the diffracted light waves even though this was not asked for by the question.

(ii) The relevant symbol equation was correctly recalled by the majority of the candidates. Since the third order maxima are obtained for both of the stated wavelengths, the smallest possible line spacing may be calculated by using the larger wavelength of 630 nm. Many candidates made the mistake of using the smaller wavelength of 540 nm to calculate their final answer.

(iii) Many of the weaker candidates did not realise that blue light would have a shorter wavelength than the two wavelengths of the light in the original beam. Stronger candidates often realised that the blue light would have a shorter wavelength, but then sometimes incorrectly deduced that this would lead to fewer than three orders of diffraction maxima.

Question 5

(a) Many candidates stated only that the sum of the e.m.f.s is equal to the sum of the p.d.s. A full statement of Kirchhoff's second law should also make reference to a loop in a circuit. The weakest candidates sometimes attempted to state Kirchhoff's first law instead of the second law.

(b) (i) 1. Most answers were completely correct. A most common mistake was to give an answer that was the reciprocal of the correct answer.

2. The correct value of the current was calculated by the majority of the candidates. A very small proportion of the candidates incorrectly assumed that the potential difference across the two external resistors was 5.6 V instead of 4.8 V.

(ii) Different methods could be used to calculate the internal resistance. The most common method was to calculate the p.d. across the internal resistance and then divide this by the current. Since this was a 'show that' question, it was essential to show every step in the calculation as well as stating the final answer. A minority of the candidates did not show explicitly that the potential difference across the internal resistance is calculated by subtracting the terminal p.d. from the e.m.f. of the battery.

(iii) The symbol formulae for the powers were usually stated correctly. Weaker candidates sometimes made errors substituting the values of the current, potential difference or resistance into those formulae.

(c) The operation of a circuit containing two batteries in series caused problems for weaker candidates who found it challenging to apply Kirchhoff's second law. The most common error was to calculate two incorrect currents using $5.6\,\text{V} / 2.5\,\Omega$ and $7.2\,\text{V} / 3.5\,\Omega$ which were then added or subtracted. Another common error was to add, instead of subtract, the e.m.f.s of the two batteries.

Question 6

(a) Many candidates stated that a field line represents the direction of the force on a charge or represents the direction in which a free charge will move, but did not specify that the charge is a positive one. The weakest candidates simply stated that field lines go from a positive plate to a negative plate or attempted to state what is meant by an electric field rather than a field line.

(b) The effect of the field strength on the field line separation was well known. Weaker candidates sometimes incorrectly described the field lines in X as being thicker lines or longer lines than the field lines in Y.

(c) (i) The strongest candidates had little difficulty calculating the correct ratio. Weaker candidates sometimes thought that the α-particle had a mass of 2 u instead of 4 u or had a charge of e instead of $2e$. Very weak candidates incorrectly assumed that the forces on the α-particle and particle P were the same because the field strength was the same.

(ii) The charge of the down quark was usually recalled correctly. A common error in the calculation of the charge of the unknown quark was to assume that particle P had a charge of $+1e$ instead of $–1e$. The candidates who were able to calculate the correct charge of the unknown quark usually went on to correctly deduce that it could be an anti-up quark, although sometimes it was incorrectly identified as being an up quark or a strange quark.

PHYSICS

Paper 9702/23
AS Level Structured Questions

Key messages

- Candidates should be able to recall precisely the laws and definitions that are referred to in the syllabus learning outcomes. A wrong or omitted key word can lead to marks not being awarded if it is an important part of a definition.
- Candidates should ensure that they do not prematurely 'round off' any intermediate answers in a numerical calculation as this can lead to an inaccurate final answer.
- In 'show that' questions, candidates should methodically present every step of their calculation as well as the final answer.
- In general, a final answer to a numerical calculation should be expressed as a decimal number and not left as a fraction.

General comments

The less able candidates had opportunities to gain credit in questions were standard definitions and substitution of given values into basic equations were required, for example in **Questions 1(a)** and **2(a)(i)**. There was also the use of basic knowledge and understanding to determine quantities or explain phenomena, for example in **Question 4(e)(i)** and in **Question 7**. A significant number of candidates were able to complete these more straightforward questions.

The questions had more challenging parts where the application of knowledge and understanding was more demanding. Examples were the showing of the kinetic energy equation in **Question 2(a)(ii)**, the determination of the area in **Question 3(b)** and the determination of the height using energy transfer in **Question 2(b)**. **Question 5** required more detailed knowledge of stationary waves in a novel situation. Only the more able candidates completed these types of question.

Comments on specific questions

Question 1

(a) (i) Some candidates gave the correct definition of resistance. A significant number attempted to give a descriptive explanation of the effect of resistance in a circuit, such as 'resistance restricts the flow of current'. There were also other incorrect answers which gave a mixture of units with quantities such as 'volt per unit current' or 'potential difference per ampere'.

(ii) The stronger candidates were able to determine the correct answer. A significant number of candidates were unable to convert GΩ into ohms to calculate the current in amperes and then convert amperes into pA. The GΩ was often given as $10^6\,\Omega$ and the pA as 10^{-9} A. Some candidates ignored both of the unit prefixes which led to an incorrect value of current.

(b) Many candidates were able to give the SI units for energy and/or charge. The stronger candidates were able to continue the analysis and derive the base units of potential difference. There were many candidates that used the coulomb or A s^{-1} for the base units of charge. Some candidates made errors in their derivation with inappropriate cancelling of the powers of the second or the metre.

Question 2

(a) (i) 1. The majority of candidates gave the correct expression for work in terms of the symbols given in the question.

2. Most candidates gave the correct expression for the distance moved in terms of the symbols given in the question. There were a large number of candidates that did not use, or were unable to rearrange, the relevant equation given on the Formulae page of the question paper.

(ii) A small minority of candidates were able to use the equations stated in **(a)(i)** to derive an equation for kinetic energy. There were very few candidates that were able to explain their working in terms of the gain in kinetic energy being equivalent to the work done. A significant number of candidates gave no response.

(b) (i) 1. Only the stronger candidates drew the correct line. Many candidates drew a horizontal line along the ground instead of along the actual path taken by the ball.

2. A majority of candidates gave the correct line for the displacement of the ball.

(ii) The stronger candidates were able to equate the original kinetic energy of the ball at X with the gain in gravitational potential energy and the kinetic energy of the ball at Y. A common error by many weaker candidates was to assume that all the original kinetic energy at X was converted to gravitational potential energy even though the ball had a speed at Y.

(iii) The majority of strong candidates sketched lines which correctly indicated a reduction in the original value of the kinetic energy at X as the ball travelled to Y. Many of the lines were curved and incorrectly showed zero kinetic energy for the ball at Y. The fact that the ball had a speed at Y was ignored by many candidates. Very few lines were straight and finished with a positive value for the kinetic energy at Y.

Question 3

(a) The majority of the stronger candidates determined the correct answer. There were a number of candidates that did not relate the rate of doing work with power. The solution used by many candidates was to determine the work done in one second by using the distance moved in one second. Most of the stronger candidates could calculate the component of force X in the direction of movement of the disc.

(b) The relevant expression for pressure was known by the majority of candidates. The correct component for force X and the correct area were calculated by the stronger candidates. A significant number of candidates did not include the weight of the disc when calculating the total force acting on the ground. A strong hint to include this force was given in the question.

(c) (i) The majority of candidates were able to state that the direction of force Y was opposite to that of the weight of the disc.

(ii) Very few candidates had the knowledge that the Earth was the body that force Y acts on. The idea that the two forces described by Newton's third law act on different bodies was not applied by most candidates. The majority of the candidates stated that force Y acts on the disc.

Question 4

(a) A significant number of candidates described the field lines as equally spaced. There were very few candidates able to describe the electric field pattern of field lines in sufficient detail for full credit to be awarded. The pattern of straight horizontal lines was stated by a small minority. The direction of the electric field was often given incorrectly or not included.

(b) The two forces acting on the charged sand particle were stated correctly by only the stronger candidates. It was unacceptable to refer to weight, electromagnetic force or electric field strength instead of electric force.

(c) Some candidates used the correct equation for the vertical motion with constant acceleration of free fall and with the initial speed as zero. The majority of candidates did not appear to realise that the vertical motion was free fall and that this motion could be treated independently of the horizontal motion due to the electric field. A significant number used the distance XY instead of using the vertical distance of fall.

(d) The correct answer was determined by a small proportion of candidates. Many candidates did not realise that the motion in the horizontal direction due to the electric field would be completed in the same time as the vertical motion due to the gravitational field. There was a considerable number that gave no response to this question.

(e) (i) The majority of the stronger candidates calculated the electric field strength correctly. There was a considerable number that gave no response to this question.

(ii) A small proportion of candidates were able to equate the electric force to the product of the mass and (horizontal) acceleration. Only the strongest candidates were able complete the calculation by using the value of the horizontal acceleration due to the electric field. There was a significant number that gave no response to this question.

(f) (i) A minority of candidates realised that the charge-to-mass ratio would not affect the acceleration of free fall.

(ii) A small proportion of candidates were able to state the effect of the change in the charge-to-mass ratio on the horizontal component of the acceleration.

Question 5

(a) Candidates found it difficult to explain the formation of stationary waves in the tube. A minority described how stationary waves are formed in general. Candidates needed to describe the reflection of the incident progressive wave at the upper open end of the tube.

(b) A large number of candidates gave the correct response.

(c) (i) A significant number of candidates gave a good description of the direction of oscillation of the particles. Many candidates did not connect the formation of the stationary wave with the incident sound wave and hence did not give the direction of oscillation for a longitudinal wave.

(ii) Many candidates did not understand that the particles that vibrate between a node and an adjacent antinode do so in phase.

(d) The majority of candidates started with the correct symbol equation. A significant number knew that the length of the tube represented half a wavelength and calculated the correct frequency.

(e) A significant number of candidates knew that the frequency was twice the frequency given in **(d)**. There was a considerable number that gave no response.

Question 6

(a) A minority of candidates gave the correct definition. Candidates should be careful not to mix quantities with units or merely state the ohm as the unit of resistance.

(b) (i) 1. The majority of candidates were able to apply Kirchhoff's first law correctly.

2. The stronger candidates were able to equate the potential difference across resistor X with the total potential difference across resistors Y and Z and then calculate the resistance of resistor Z.

3. The stronger candidates added the potential differences across one branch of the parallel combination and the internal resistance to obtain the e.m.f. of the battery. The weaker candidates tended to omit the potential difference across the internal resistance, or gave the potential difference across the internal resistance as the e.m.f. of the battery. A significant number attempted to calculate the total resistance of the circuit treating the resistors as all in series or all in parallel.

(ii) 1. The stronger candidates made a good start by stating the equation $R = \rho l / A$ and then deduced the correct ratio. A significant number of candidates made arithmetic errors in using this symbol equation to determine the ratio or gave no response.

2. A small number of candidates determined the correct ratio. Many assumed the current was the same through each resistor. The rearrangement of the relevant symbol equation and then the subsequent substitution of values also caused many candidates to make errors. There was a considerable number that gave no response to this part.

Question 7

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

(b) The majority of candidates were aware of quarks being present in α-particles.

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

(d) Candidates found this the most difficult part of the question, and a minority of candidates gave the correct response. A significant number considered γ-radiation to be emitted in radioactive decay with a continuous range of energies rather than particular energy values.

PHYSICS

Paper 9702/31
Advanced Practical Skills 1

Key messages

In choosing the number of decimal places when recording raw readings, candidates need to relate to the precision of the measuring device, e.g. angles can be read to the nearest degree and lengths (with a ruler) to the nearest millimetre. The number of significant figures in a collection of raw data does not need to be the same (especially when the values range from units to tens) but the number of decimal places must remain the same to reflect the measuring instrument used.

Calculated values should be rounded correctly to gain credit and not merely truncated.

Candidates need to use a sharp pencil to draw both plotted points and lines of best fit. Plotted points should be drawn as neat crosses and not as 'blobs' greater than half a square in diameter, and lines should be continuous, thin and straight. A transparent 30 cm ruler should be used for drawing lines of best fit.

In order to calculate the percentage uncertainty in a measurement, some judgement has to be made about the absolute uncertainty of the measurement. Candidates often just use the precision of the instrument as an indication of the experimental uncertainty in a measurement, but this is often an underestimate of the true uncertainty.

To be successful answering **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. To practise and develop this skill, either candidates should be encouraged to look at the experiment chronologically stating the limitations as they encounter them, or to focus in on the difficulties of the measurements that are collected.

General comments

There was no evidence that centres generally had difficulties in providing the equipment required for use by the candidates. It was clear that most centres work hard to provide the equipment specified in the Confidential Instructions.

Any deviation between the requested equipment and that provided to the candidates should be written down in the Supervisor's Report, and this report must be sent with the scripts to Cambridge so that the Examiners can take this into consideration when marking. No 'extra' equipment should be available to the candidates. In some cases this may disadvantage candidates.

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

Successful answers showed the apparatus had been used well, and there were many very good answers. Both questions were normally attempted and there did not seem to be a shortage of time in most cases. Good practical skills were demonstrated in the generation and handling of data. Some candidates could improve by giving more thought to the analysis and evaluation of experiments.

Comments on specific questions

Question 1

(a) Stronger candidates correctly noted a value for the coiled length of the spring *v* which was in the appropriate range, to the nearest mm and with a correct unit. Weaker candidates often gave values to the nearest whole cm, added an extra zero or omitted the unit altogether.

(b) With the rule, strings and spring correctly arranged, successful candidates stated values for the distances *x* and *y* where the value of *x* was less than the value of *y*.

(c) Most candidates recorded six sets of readings and gave new values of *x* and *y* following adjustment of the apparatus in neatly presented tables with the table values showing the correct trend. Stronger candidates included *x* values above and below 50 cm. Weaker answers showed *x* values which were either all above 50 cm or all below 50 cm.

Stronger candidates included a correct quantity and unit in every column heading. These answers included a separating mark, such as a solidus, between the quantity and unit e.g. *x* / cm. Weaker candidates often omitted units or did not include a separating mark between the quantity and its unit.

Consistent answers reflected the precision of the metre rule, so all readings of raw *x* and *y* were given to the nearest mm. Some candidates gave *x* and *y* values to the nearest cm or gave all mm values as zero.

(d) (i) Stronger candidates used axes for their graphs that were labelled with the appropriate quantities e.g. *x* or *y*. Weaker candidates tended to only state units or omitted the labels altogether. It is important that candidates select sensible scales. Weaker candidates often used most of the graph grid but did this by using difficult scales, e.g. one large square equal to 0.6 or 0.3. Such scales are very difficult to work with and can cause the candidate to make mistakes in several different places. Better answers used a scale which was easy to interpret with the value of one small square equal to, for example, 1.0 or 0.5.

Some candidates used scales with values missing, e.g. 60, 70, 90 (where 80 is missing).

The strongest candidates had points spreading over more than half the grid. In successful answers with a graph in portrait orientation, points occupied (spread into) six or more large squares in the vertical direction and four or more large squares in the horizontal direction. Weaker candidates often used a scale such that points were squashed into a small area, in some cases just two large squares.

Candidates should take care to plot points accurately within half a small square in both the *x* and *y* directions. Many graphs could be improved by the use of a sharp pencil to draw fine points so that the points have a diameter less than half a small square.

(ii) Some candidates were able to draw carefully considered lines of best fit. Others joined the first and last points on the graph or any three points on a straight line regardless of the distribution of the other points. There should always be a balanced distribution of points either side of the line along the entire length. Many lines needed rotation to get a better fit, or an anomalous point needed to be identified to justify the line drawn. Some candidates were not awarded credit because their lines were kinked in the middle, a double line or drawn freehand without the aid of a ruler.

(iii) Successful answers clearly showed how to find the gradient and intercept of a straight line graph.

Good gradient calculations used a large triangle, i.e. one for which the hypotenuse was greater than half the length of the drawn line. Weaker gradient calculations used read-offs from a small triangle where the hypotenuse was less than half the drawn line. Good calculations had accurate read-offs substituted correctly into $(y_2 - y_1) / (x_2 - x_1)$ with working that was clear to follow. Some candidates incorrectly substituted into $(x_2 - x_1) / (y_2 - y_1)$. Some candidates used values from the table that were not on the line rather than taking points from the line.

In finding the intercept, stronger candidates either read off the *y*-intercept directly from the graph where $x = 0$ or substituted values for *x* and *y* using a point on the line correctly into $y = mx + c$. When rearranging this equation, candidates should obtain $c = y - mx$. Some candidates incorrectly used $c = y / mx$. It was also common for candidates to find the intercept by taking a read-off where the line cut the *y*-axis at a point other than $x = 0$, giving a false origin.

(e) Candidates needed to make a direct transfer of values from **(d)(iii)** to **(e)**. *P* was equal to the value of the gradient and *Q* was equal to the value of the intercept, and no additional calculations were necessary. Weaker answers recorded fractions for *P* or *Q* or showed fresh substitutions into the equation and further calculations.

Some candidates did not include the units or gave wrong units.

(e) Many candidates calculated *R* correctly. Weaker answers had errors in calculations, often caused by incorrect rearrangement of the equation. Some candidates recorded a final value after truncating rather than rounding.

Successful treatment of significant figures was shown when the calculated value for *R* was recorded to three significant figures as requested. Weaker candidates often incorrectly considered an answer such as 0.089 to have three significant figures.

Question 2

(a) (i) Most candidates carefully measured the diameter and height of the larger lid. Good answers showed measured values of the distances recorded to the nearest mm. Weaker candidates had a value of '1 cm' for *t* rather than giving an answer to the nearest mm. Measuring the small distance *t* with a rule was difficult owing to the rounded shape of the edge, and this could be stated as a source of limitation in **(g)**.

(ii) Many candidates showed repeat readings of *d*. Some candidates gave the smallest division on the rule, i.e. 1 mm, as the absolute uncertainty. When readings were repeated, some successful candidates showed clearly the absolute uncertainty found by calculating half the range of repeated values. Successful candidates who used an estimate of the absolute uncertainty chose a value in the range 2–5 mm.

(b) (i) Most candidates used the equation to correctly calculate a value for volume *V*. Weaker candidates truncated their answer rather than rounding correctly.

(ii) Candidates needed to be specific and relate the number of significant figures in the value of *V* to the number of significant figures in the values of *d* and *t*. Successful answers referred specifically to *d* and *t* (i.e. the relevant quantities in this question). Weaker answers stated vague quantities such as 'raw data' or 'values in the calculation', referred to the precision of the ruler or to decimal places, or gave a bald statement such as '3 significant figures'.

(c) Successful candidates recognised that this measurement was difficult and noted down repeat readings showing the experiment had been done more than once. Weaker candidates often had just one value of *n*.

(d) Most candidates showed that the smaller lid had been used to record second values of *d*, *t* and *n*. A smaller lid should have produced a smaller value for *n* if the experiment was carefully carried out. Some weaker candidates found that a smaller lid produced a larger *n*.

(e) (i) Stronger candidates showed the correct rearrangement of the equation and calculated *k* for both experiments. If answers showed repeated measurements, successful candidates used the latest or mean measurements taking them through into the calculation of *k*. Some weaker candidates rounded in the middle of the calculations and produced inaccurate values.

(ii) Successful candidates had three steps in their argument. They first stated 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 **(a)(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’.

Some candidates did not give any criterion to test against. Many statements were too vague. Some candidates looked at the difference without determining a percentage, or gave an answer that did not logically follow from the data. These could not be awarded credit.

(f) Stronger answers showed a correct calculation for *M* in grams stating a final answer with a consistent unit and in the expected range. Often weaker candidates confused the power of ten when choosing to change density into $kg\,m^{-3}$, and then obtained an answer out of range.

(g) **Question 2** is designed to have challenges when taking measurements. Often there is other apparatus that could be used to ensure more accurate measurements. Successful candidates discussed limitations discovered while experimenting, stating these in **(i)**. Answers were often improved in **(ii)** by stating a valid method or suggesting other apparatus that could be used to take more accurate measurements.

Stronger candidates stated ‘only two lids were used to test the relationship and this is not enough to draw a conclusion’. Weaker answers just stated ‘two readings are not enough’ or ‘two sets of readings are not enough to take accurate readings’. To improve on this idea of two sets of readings being insufficient, weaker candidates often made suggestions to ‘take more readings’ or ‘take more readings and find the average’, neither of which were sufficient.

The stronger candidates were able to identify genuine limitations in this experiment. Weaker answers had ideas that were vague or could have been avoided by careful technique, such as miscounting coins, not knowing the position of the centre of a lid, or suggested that the water removed with the coins changed the volume of water in the container and therefore affected *n*. None of these were valid problems here. Some candidates suggested changes to the actual apparatus being measured, e.g. ‘supply lids with straight sides’. Experimenters in science are often presented with a measurement that is challenging to make, but a better method of making the measurement needs to be found rather than changing the object that is being measured.

Stronger candidates stated that the difficulty in measuring *t* lay in the curved shape of the edge of the lid leading to parallax error. Alternatively stronger candidates suggested that, because *t* was small, there was a large percentage uncertainty in the value. Weaker answers simply stated ‘it was difficult to measure *t*’ or that there was parallax error without identifying which quantity was being measured.

Loading the lid with coins while ensuring the lid remained horizontal on the surface was difficult as the lid tended to tilt. Stronger candidates noted that it was difficult to place the coins without the lid tilting or applying extra force as a coin was dropped, and that consequently the lid would sink with fewer coins. Stronger candidates suggested that the use of a guide on the lid or using tweezers would be an improvement. Some weaker candidates noted that ‘the lid sank too soon’ as a difficulty and ‘the coins should be placed evenly’ as an improvement without suggesting a method for loading the coins evenly.

The coins may not all have the same mass. Some candidates suggested using a balance or scales to measure the mass of the coins. Weaker candidates just stated ‘ensure all coins have the same mass’ without the detail of the method to be used. Related to this were issues connected with the coins being wet: when the coins were wet, their mass was increased. An improvement here would be a method for drying the coins e.g. using towel or a hot air dryer.

Candidates need to suggest detailed limitations and improvements that are specific to this experiment. Statements of general errors e.g. ‘systematic errors’, ‘zero errors’ or ‘rules with uneven ends’ cannot be given credit. Some weaker answers stated, for example, ‘repeat measurements and calculate averages’ or included general statements such as ‘view scale at eye level’ or ‘look at right angles to avoid parallax’. Again these statements are not specific enough be given credit, and candidates should be encouraged to give detail that is specific to the particular experiment they are carrying out.

PHYSICS

Paper 9702/32
Advanced Practical Skills 2

Key messages

- In choosing the number of decimal places when recording raw readings, candidates need to relate to the precision of the measuring device, e.g. angles can be read to the nearest degree and lengths (with a ruler) to the nearest millimetre. The number of significant figures in a collection of raw data does not need to be the same (especially when the values range from units to tens) but the number of decimal places must remain the same to reflect the measuring instrument used.

- Calculated values should be rounded correctly to gain credit and not merely truncated.

- Candidates need to use a sharp pencil to draw both plotted points and lines of best fit. Plotted points should be drawn as neat crosses and not as 'blobs' greater than half a square in diameter, and lines should be continuous, thin and straight. A transparent 30 cm ruler should be used for drawing lines of best fit.

- In order to calculate the percentage uncertainty in a measurement, some judgement has to be made about the absolute uncertainty of the measurement. Candidates often just use the precision of the instrument as an indication of the experimental uncertainty in a measurement, but this is often an underestimate of the true uncertainty.

- To be successful answering **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. To practise and develop this skill, either candidates should be encouraged to look at the experiment chronologically stating the limitations as they encounter them, or to focus in on the difficulties of the measurements that are collected.

General comments

There was no evidence that centres had any serious difficulties in providing the equipment required for use by the candidates. The Supervisor's Reports from many centres included useful detail about the apparatus and about difficulties encountered in the experiments and any help provided. Such detail is useful to the Examiners who can take it into account when marking candidates' work.

For many centres the candidates' work was of a good standard, with data and graphs presented clearly. There did not seem to be a shortage of time and all sections of the two questions were answered by almost all the candidates.

Comments on specific questions

Question 1

(a) After constructing the circuit, candidates were asked to set the contact near to the midpoint of the wire. Most candidates correctly recorded a value of x close to 50 cm.

(b) Nearly all candidates found a balance length y which was less than x, suggesting correct operation of the circuit.

(c) Most results tables contained six or more sets of values. In a few cases the trend was wrong, and this was probably caused by a reversed metre rule scale. The stronger candidates took readings over a large part of the available range.

Tables from many candidates were neatly presented, though some were untidy. Candidates should be encouraged to present their tables neatly as this makes it much easier to then carry out calculations correctly and plot the right data. Most headings included a correct unit with a clear separating mark between the quantity and its unit.

Stronger candidates recorded all of their *x* and *y* values to the nearest mm.

Most calculations were correct, apart from a small number of rounding errors. The strongest candidates were credited for using the correct number of significant figures in their calculated quantities, though many weaker candidates found this difficult.

(d) (i) There were many very good graphs. These had scales chosen to give simple intervals (using ratios of 1, 2 or 5) as well as making good use of the available grid area.

Candidates who used small crosses or small circled dots produced the clearest plotted points. The use of large dots (with diameter greater than 1 mm) cannot be given credit because their accuracy cannot be judged.

In many cases the scatter of the candidates' data was low and so credit was awarded for the quality of the data.

(ii) Stronger candidates drew suitable lines of best fit which had a balanced distribution of points either side along the entire length. In some cases, a stray point was apparently ignored without explanation. If such a point is to be ignored in assessing the line of best fit, the anomalous point should be labelled clearly (e.g. by circling the point). Candidates should be advised not to do this for more than one point.

(iii) Nearly all candidates knew how to find the gradient of their line. Most candidates took values from their line and carried out the procedure accurately, and showed their working clearly. Some used too small a triangle. Candidates need to check that the triangle for calculating the gradient is large enough (the hypotenuse should be greater than half the length of the line drawn).

The intercept value could often be read directly off the *y*-axis. If this was not possible, candidates generally knew how to calculate the intercept using their gradient value.

(e) Most candidates recognised that *a* was equal to the value of the gradient and *b* was equal to the intercept. A large number of candidates included correct units for their *b* value and correctly showed *a* without a unit.

Question 2

(a) After assembling the apparatus, candidates were asked to measure the angle between the board and the bench. The value was usually in the acceptable range. In a few cases it was stated to a tenth of a degree and this is a precision that is not possible when using a protractor with 1° divisions.

(b) Stronger candidates repeated the process of pulling the block up the ramp several times, recording a value for each trial as well as calculating an average. Most values were correctly recorded to the nearest 0.1 N.

(c) The absolute uncertainty in *F* depended on the fluctuation of the reading as well as the precision of the meter itself. Many candidates either estimated a practical value (± 0.2 N or more) or calculated half the range of their repeated measurements.

(d) (i) Most of the candidates repeated the tests using a smaller angle θ for the board and gained credit for recording a second value of θ.

(ii) Most candidates obtained a second value of *F* and found that the value of *F* was smaller, as expected.

(e) Candidates were asked to find the weight of the block using the newton meter. Most recorded a value in the expected range and included the unit N. A small number of candidates mistakenly recorded the mass of the block and then multiplied by *g* to find the weight.

(f) (i) The calculation to find μ was carried out accurately by most candidates.

(ii) The evaluation of the suggested relationship was carried out well by many candidates. They looked at the variation between the two μ values (usually by calculating the percentage difference) and then compared it with what they considered as allowable for this experiment (e.g. 20%, or the percentage uncertainty they had calculated for *F* earlier).

(g) The use of the formula to predict a value for *F* with a board angle of 65° was correct for the majority of candidates, with the value stated to a sensible number of significant figures.

(h) (i) In carrying out this simple experiment, most candidates readily identified several areas of difficulty with the procedures and apparatus (e.g. fluctuating force, instability of board, uncertainty in readings). Credit was given for sufficiently detailed descriptions of these problems as long as they could not be overcome using the available apparatus by working more carefully.

Many candidates stated that it was difficult to measure the angle θ because the centre (the origin) was above the base of the protractor. This was not accepted because θ could be measured at any height above the bench, and the origin could be brought into contact with the edge of the board by sliding the protractor along the bench.

Stronger candidates recognised that although the newton meter increments were small (0.1 N), the force itself was also small, so there was a large percentage uncertainty in *F*.

(ii) Most candidates suggested improvements to the problems they had described in **(i)**, with some reference to the relevant measurement or item of equipment.

Many candidates suggested using a motor to pull the block at constant speed. Since the newton meter readings fluctuated as the block was pulled, the idea of recording a video of its scale and then viewing in slow motion was accepted as a useful aid in estimating a mean value for *F*.

The suggestion of using a heavier block to increase the *F* values (thus reducing the percentage uncertainty) was not accepted because the experiment was about the block that was provided. However, some candidates suggested putting a mass on top of the block (to produce the same effect), and this was credited.

The need for a newton meter with greater precision was often recognised, but many candidates just suggested using 'electronic' or 'digital' meters without specifying that the meter needed to have a better precision.

The key to this section is for candidates to identify genuine problems associated with setting up this experiment and in obtaining readings. Candidates are then encouraged to suggest practical solutions that either improve technique or give more reliable data. Clarity of thought and expression separated the stronger candidates from those less prepared to deal with practical situations and the limitations. Candidates should be encouraged to write about four different problems (perhaps relating to the different measurements undertaken or chronologically going through the experiment) stating <u>how</u> these difficulties impact on the experiment. Candidates should then try to think of associated solutions that address each of these problems.

PHYSICS

Paper 9702/33
Advanced Practical Skills 1

Key messages

- In choosing the number of decimal places when recording raw readings, candidates need to relate to the precision of the measuring device, e.g. angles can be read to the nearest degree and lengths (with a ruler) to the nearest millimetre. The number of significant figures in a collection of raw data does not need to be the same (especially when the values range from units to tens) but the number of decimal places must remain the same to reflect the measuring instrument used.

- Calculated values should be rounded correctly to gain credit and not merely truncated.

- Candidates need to use a sharp pencil to draw both plotted points and lines of best fit. Plotted points should be drawn as neat crosses and not as 'blobs' greater than half a square in diameter, and lines should be continuous, thin and straight. A transparent 30 cm ruler should be used for drawing lines of best fit.

- In order to calculate the percentage uncertainty in a measurement, some judgement has to be made about the absolute uncertainty of the measurement. Candidates often just use the precision of the instrument as an indication of the experimental uncertainty in a measurement, but this is often an underestimate of the true uncertainty.

- To be successful answering **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. To practise and develop this skill, either candidates should be encouraged to look at the experiment chronologically stating the limitations as they encounter them, or to focus in on the difficulties of the measurements that are collected.

General comments

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

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

The general standard of the work done by the candidates was good, and there were many excellent scripts. Candidates did not seem to be short of time and both questions were attempted by most 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

(a) Many candidates stated a value for x in the appropriate range and with a unit. Some candidates stated a value outside the range or omitted the unit. Some values were impossible to obtain (e.g. $x > 50.0$ cm) suggesting a scale reading from the ruler instead of the length x. A minority of candidates stated x in inches instead of cm.

(b) Some candidates stated values of T in the appropriate range, with evidence of repeats of more than one set of oscillations. Many candidates did not repeat sets of oscillations (e.g. a single set of $5T$ was often seen). Candidates should be encouraged to take multiple (e.g. 3) sets of $5T$ or $10T$.

Some candidates could not be awarded credit because they did not state the number of oscillations they were timing and gave a final answer outside the permissible range. Some candidates misinterpreted the stop-watch (e.g. 0:00:08 was read as 0.8 s). Other candidates provided a single value of T without any working. A few candidates confused the period with frequency and, having found T, then calculated f and stated this as their final answer for T.

(c) Many candidates were able to collect five sets of values of x and T without assistance from the Supervisor. Some candidates collected more results. Very few candidates collected four sets or fewer.

Many candidates did not reduce their x value from 20 cm. Candidates should be encouraged to make use of the whole metre rule provided.

Many candidates were awarded credit for the column headings, stating the quantity and correct unit. Some candidates omitted either the unit or the separating mark for one of the columns.

Many candidates correctly recorded their raw values for x to the nearest 0.1 cm. Some candidates stated their measurements to the nearest cm e.g. '5 cm' without considering that they can make the measurement to the nearest mm using the ruler provided. Some candidates added on a trailing zero to the end of their number if it was less than 10.0 cm in order to make the number of significant figures the same down the column. This cannot be awarded credit because the number of decimal places is then inconsistent with the precision of the ruler.

Overall the table work was done well by candidates. Some candidates overcomplicated the experiment by inadvertently working out the frequency instead of the period, which resulted in the wrong trend being obtained. Some candidates rounded their measured times to 1 or 2 significant figures, which then resulted in data that did not show the correct trend.

(d) (i) A few candidates omitted labels or marked their scales with gaps that were too large. Compressed scales (i.e. where the points occupy less than half the grid) were often seen and could not be given credit. This may have arisen because of the candidates' perceived need to start the graph at the origin. Candidates should be reminded that they will often need to select scales that do not begin at zero in order to make full use of the graph grid.

There were many awkward scales used by candidates (e.g. based on 3 or 6). A minority of candidates set the minimum and maximum reading in the table to be the minimum and maximum of the graph grid, leading to time-consuming work plotting and using the scales. Awkward scales cannot be awarded credit and it was very common for candidates using such scales to make further mistakes later for incorrect read-offs. A few candidates labelled the scale markings with their point readings from the table or used non-linear scales, and these also cannot be awarded credit. Candidates should be encouraged to set up their graphs to make them easy to work with in later parts of the question.

Some points were drawn as dots with a diameter greater than half a small square ('blobs'). Many points were incorrectly plotted so that they were greater than half a small square from the correct location. If a point seems anomalous, candidates should be encouraged to check the plotting and to repeat the measurement if necessary. If such a point is ignored in assessing the line of best fit, the anomalous point should be labelled clearly e.g. by circling the point (with no more than one point being circled). There is no credit specifically for identifying an anomalous point, so candidates should be reminded that they do not need to identify an anomalous point if they do not think they have one.

(ii) Some candidates were able to draw carefully considered lines of best fit. Others joined the first and last points on the graph or any three points on a straight line regardless of the distribution of the other points. There should always be a balanced distribution of points either side of the line along the entire length. Many lines needed rotation to get a better fit, or an anomalous point needed to be identified to justify the line drawn. Some candidates were not awarded credit because their lines were kinked in the middle, a double line or drawn freehand without the aid of a ruler.

(iii) Some candidates used a suitably large triangle to calculate the gradient, gaining credit for correct read-offs, and substituted into $\Delta y / \Delta x$. Other candidates needed to check that the read-offs used were within half a small square of the line of best fit and show clearly the substitution into $\Delta y / \Delta x$ (not $\Delta x / \Delta y$). The equation $m(x - x_1) = (y - y_1)$ should be shown with substitution of read-offs.

Some weaker candidates omitted the minus sign from their calculated gradient when their actual gradient was negative.

Candidates need to 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, and many candidates would benefit from double-checking their read-offs.

Many candidates were able to correctly read off the y-intercept at $x = 0$ directly from the graph, but a large number of candidates incorrectly read off the y-intercept when there was a false origin. Some candidates correctly substituted a read-off into $y = mx + c$ to determine the y-intercept. Others needed to check that the point chosen (if it was from the table) was on the line drawn.

(e) Most candidates recognised that P was equal to the gradient and Q was equal to the intercept. Some candidates stated incorrect units (e.g. Q / cm) or omitted the units.

(f) Most candidates substituted their values of P, Q and T to calculate x correctly. Many candidates found it difficult to rearrange the equation correctly and to give the answer to three significant figures.

Question 2

(a) (i) Most candidates measured values of θ in the appropriate range and to the nearest degree. Some candidates stated the angle measurement to the nearest tenth of a degree (e.g. 25.1°) when this was not possible with the protractor provided.

(ii) Many candidates correctly calculated (sin 2θ)(cos 2θ). Some candidates' calculators were set in radian mode while some weak candidates incorrectly obtained numbers greater than 1 and often close in size to the angle.

(iii) Many candidates correctly justified the number of significant figures they had given for the value of (sin 2θ)(cos 2θ) with reference to the number of significant figures in θ. Many candidates gave reference to just 'raw readings' or 'values in calculation' without stating what these values were.

(b) Many candidates stated their raw readings to the nearest mm and with the mean d within the appropriate range. Some candidates omitted the unit, stated d to the nearest cm, or measured d so that it was outside the expected range.

(c) (i) Most candidates stated a value of h with a unit. A few candidates stated measurements with an incorrect power of ten, e.g. 30 m when they probably meant to write 30.0 cm.

(ii) Most candidates are familiar with the equation for calculating percentage uncertainty and many gave an uncertainty in h that was in a sensible range for this experiment. Some candidates made too small an estimate of the absolute uncertainty in the value of h, typically 0.1 cm or 0.05 cm or too large an estimate, typically 10.0 cm.

Many candidates considered the uncertainty as being only the precision of the measuring instrument, yielding an answer that was too small. Some candidates repeated their readings and correctly gave the uncertainty in *h* as half the range.

(d) Most candidates recorded second values of θ, *d* and *h*. Some weaker candidates gained a second *h* value that was less than the first, suggesting that the experiment had not been carried out correctly.

(e) (i) Most candidates were able to calculate *k* for the two sets of data, showing their working clearly. A minority of candidates incorrectly rearranged the equation algebraically to calculate $1/k$ or inadvertently substituted the wrong values.

(ii) Some candidates calculated the percentage difference between their two values of *k*, and then tested it against a specified numerical percentage uncertainty as a criterion, commonly using 10%, 20% or the percentage uncertainty calculated for *h*. Some candidates omitted a criterion, or gave a general statement such as 'this is valid because the values are close to each other' or 'strongly supported' without any working, which could not be accepted.

(f) Many candidates recognised that two sets of data were insufficient to draw a valid conclusion and stated an improvement of taking more readings and plotting a graph. Some problems stated by candidates correctly related to the measurements taken with a valid reason, although there were many identified problems that were not linked to the experiment.

Various reasons for difficulty in measuring *d* and *h* were given, such as having to hold the ruler vertically or horizontally in mid-air, or there was parallax error in these measurements. Also commonly seen were limitations relating to the difficulty in aligning the ball vertically so that the ball fell on the dot or judging whether the ball actually hit the line A or B on the card. To gain credit, the quantity that was difficult to measure should be specified along with the difficulty. Statements of just 'parallax error', 'parallax error while reading values', 'hard to measure distance' or 'difficult to measure *h*' without clarification could not be given credit. There was no particular difficulty in measuring the angle for this experiment as the protractor could be aligned against the board and rested on the table.

Credit is not given for suggested improvements that could be carried out in the original experiment, such as 'repeat measurements', 'do more readings to get an average value', 'look perpendicularly onto the ruler' etc. Unrealistic solutions were also not given credit, e.g. 'robotic arm' or 'mechanical hand' to release the ball. The use of video cameras was mentioned frequently but it was not always a correct use (e.g. candidates stated that it was for measuring *h* instead of helping to see whether the ball hit the line). Problems that were irrelevant or that could have been removed if the candidate had taken greater care were not given credit. Vague or generic answers such as 'too few readings' (without stating a consequence), 'faulty apparatus', 'use of a fiducial marker' (as this was not relevant in this experiment), 'digital protractor' or 'use an assistant' were also not given credit.

The key to this section is for candidates to identify genuine problems associated with setting up this experiment and in obtaining readings. Candidates are then encouraged to suggest practical solutions that either improve technique or give more reliable data. Clarity of thought and expression separated the stronger candidates from those less prepared to deal with practical situations and the limitations. Candidates should be encouraged to write about four different problems (perhaps relating to the different measurements undertaken or chronologically going through the experiment) stating <u>how</u> these difficulties impact on the experiment. Candidates should then try to think of associated solutions that address each of these problems.

PHYSICS

Paper 9702/34
Advanced Practical Skills 2

Key messages

- In choosing the number of decimal places when recording raw readings, candidates need to relate to the precision of the measuring device, e.g. angles can be read to the nearest degree and lengths (with a ruler) to the nearest millimetre. The number of significant figures in a collection of raw data does not need to be the same (especially when the values range from units to tens) but the number of decimal places must remain the same to reflect the measuring instrument used.

- Calculated values should be rounded correctly to gain credit and not merely truncated.

- Candidates need to use a sharp pencil to draw both plotted points and lines of best fit. Plotted points should be drawn as neat crosses and not as 'blobs' greater than half a square in diameter, and lines should be continuous, thin and straight. A transparent 30 cm ruler should be used for drawing lines of best fit.

- In order to calculate the percentage uncertainty in a measurement, some judgement has to be made about the absolute uncertainty of the measurement. Candidates often just use the precision of the instrument as an indication of the experimental uncertainty in a measurement, but this is often an underestimate of the true uncertainty.

- To be successful answering **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. To practise and develop this skill, either candidates should be encouraged to look at the experiment chronologically stating the limitations as they encounter them, or to focus in on the difficulties of the measurements that are collected.

General comments

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

Some candidates were given metal weights (e.g. slotted masses) or other materials for **Question 2** instead of the rocks specified in the Confidential Instructions. Centres that are unable to provide the exact equipment listed in the Confidential Instructions should contact Cambridge at the earliest opportunity to discuss possible alternatives to the equipment listed.

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. Supervisors are also reminded to submit both a sample set of results and the Supervisor's Report.

The general standard of the work done by the candidates was good, and there were many excellent scripts. Candidates did not seem to be short of time and both questions were attempted by most 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

(a) Most candidates recorded a value for α that was in the range 46–52°, to the nearest whole degree. Some candidates recorded (raw) values that were to the nearest 0.1°, which was too great a level of precision for the protractor.

(b) Almost all candidates recorded a value for β that was greater than $\alpha/2$. A few candidates misread the scale on the protractor, recording a value for β that was greater than 90°.

(c) Almost all candidates were able to record six sets of values of *x* and β successfully, showing the correct trend.

Only the strongest candidates made the best use of the possible range of values of *x*. To make full use of the apparatus, candidates needed to use the holes nearest to, and furthest away from, point A.

Most candidates labelled their table of results correctly by including a quantity and a unit (where appropriate) for each column heading. Some candidates did not separate the angle β from its unit, writing β° (or occasionally β°C). Others incorrectly gave a unit, usually °, for the column headed tan ($\beta - \alpha/2$).

Most candidates recorded all their raw values of *x* to the nearest mm, though some only recorded their raw values for *x* to the nearest cm. A small number of candidates added an extra zero to all their values (e.g. 2.00 cm) to give the false impression of greater precision in their measurements. For 'static' measurements, such as *x* and β in this experiment, there is no merit in repeating the measurement, since the measurement does not change. Each measurement should be made and recorded, carefully, once only.

The great majority of candidates calculated and recorded their values for tan ($\beta - \alpha/2$) correctly, and to an appropriate number of significant figures (2 or 3).

A few candidates only recorded values of ($\beta - \alpha/2$), omitting to calculate tan ($\beta - \alpha/2$). These candidates then plotted a graph of ($\beta - \alpha/2$) against *x* and could not be awarded credit for plotting the correct graph.

(d) (i) Candidates were required to plot a graph of tan ($\beta - \alpha/2$) on the *y*-axis against *x* on the *x*-axis. Most gained credit for drawing appropriate axes, with labels and sensible scales.

A few candidates chose extremely awkward scales, making the correct plotting of points much more demanding. Some chose the highest and lowest values in their tables as the lowest and highest points on their graph scales and then calculated intermediate values. Although this appears to make the maximum use of the graph grid, it makes it very difficult to plot all the points correctly. These candidates cannot be awarded credit for the axes, and they often make further mistakes later with incorrect read-offs when calculating the gradient or the *y*-intercept of the line.

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

Some candidates needed to take care to draw the plotted points so that the diameters of the points were equal to, or less than, half a small square. A small but clear pencil cross, or a point with a circle, is recommended.

(ii) Many candidates were able to draw a straight line, which was a good fit to the points plotted, with a reasonable distribution of points above and below the line. Weaker candidates tended to join the first and last points on the graph, regardless of the distribution of the other points, or draw a line which could clearly be improved by rotation. A few candidates drew a double line or a line with a kink in it.

(iii) Some candidates used a suitably large triangle to calculate the gradient, gaining credit for correct read-offs, and substituted into $\Delta y / \Delta x$. Other candidates needed to check that the read-offs used were within half a small square of the line of best fit and show clearly the substitution into $\Delta y / \Delta x$ (not $\Delta x / \Delta y$). The equation $m(x - x_1) = (y - y_1)$ should be shown with substitution of read-offs.

Some weaker candidates omitted the minus sign from their calculated gradient when their actual gradient was negative.

Candidates need to 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, and many candidates would benefit from double-checking their read-offs.

Many candidates were able to correctly read off the *y*-intercept at $x = 0$ directly from the graph. Some candidates correctly substituted a read-off into $y = mx + c$ to determine the *y*-intercept. Others needed to check that the point chosen (if it was from the table) was on the line drawn.

(e) Most candidates recognised that *P* was equal to the value of the gradient and *Q* was equal to the value of the intercept calculated in **(d)(iii)**.

The majority of the candidates recorded correct units for *P* (e.g. cm^{-1}) and no units for *Q*; others omitted the units for *P* or included degrees (°) in their units for one or both quantities.

Question 2

(a) Most candidates determined the value of *c* to the nearest mm, with a unit and in the appropriate range.

(b) Almost all candidates were able to record a value for *d* that was less than *c*.

(c) Candidates were asked to estimate the percentage uncertainty in their value of *d*. Most were familiar with the equation for calculating percentage uncertainties, but many underestimated the absolute uncertainty in the value of *d*. This is dependent not only on the precision of the metre rule, but also on the errors in judging the position of the centre of the mass and possible parallax errors. A realistic estimate for the absolute uncertainty in the measurement of the value of *d* is in the range 0.2–1.0 cm.

(d) All candidates recorded second values of *c* and *d* successfully. Most candidates correctly obtained values that were smaller than the values for the larger rock.

(e) (i) Most candidates were able to calculate the two values for *k* correctly. Some candidates could not be awarded credit because they calculated $1 / k$, or recorded their values on the answer lines to only 1 significant figure. Both *c* and *d* should be recorded to at least 2 significant figures, so *k*, which is calculated from these values, should be recorded to at least 2 or 3 significant figures.

(ii) Some candidates recognised that the appropriate number of significant figures for *k* is determined by the significant figures of *c* **and** $(c - d)$, whichever is the smaller. Others referred only to the 'raw data' which was too vague to be awarded credit.

(iii) Candidates were asked to explain whether their results supported a suggested relationship – in other words, allowing for the uncertainties in the measurements, whether the two values of *k* could be regarded as equal. To do this, candidates need to test the hypothesis against a specified numerical percentage uncertainty, either taken from **(c)** or estimated themselves.

Where candidates state a percentage uncertainty value, it is a good idea to try to justify this value in some way, particularly if a very large percentage uncertainty is suggested.

Most candidates were able to calculate the percentage difference between the two values of *k*, and then compare this difference to an estimated overall uncertainty for the experiment (e.g. 20%). Some candidates gave answers such as 'the difference between the two *k* values is very large/quite small' which is insufficient – a numerical percentage comparison is needed.

(f) The majority of candidates were able to calculate a value for the density of the larger rock by substituting the first value for *k* into the equation given. Some candidates substituted the second value of *k* (for the smaller rock).

Most candidates were able to obtain a value for the density in the expected range.

(g) Many candidates recognised that two sets of data were insufficient to draw a valid conclusion, though some confused conclusions with results.

In this experiment, the main difficulties included problems getting the wooden strip to balance on the pivot (with or without the rock and mass on the strip), and problems obtaining accurate values for *c* and *d* (because of the uncertainty in the position of the centre of the mass). Hanging the rocks exactly 30.0 cm from the centre mark was also a source of error because of the thickness of the string. Many candidates also recognised that the string supporting the rocks affects the experiment in a variety of ways.

Some candidates simply described measurements that were difficult to make without explaining why they were difficult, e.g. 'it was difficult to measure *c* accurately because the position of the centre of the mass was not clear'.

Valid improvements included taking more readings for different sized rocks and then plotting a suitable graph to test the suggested relationship. Some candidates suggested calculating further values for *k* and then calculating an average value, implying that *k* is constant. They should instead state that the values of *k* should be *compared* with each other to see if *k* being constant is a valid conclusion.

The key to this section is for candidates to identify genuine problems associated with setting up this experiment and in obtaining readings. Candidates are then encouraged to suggest practical solutions that either improve technique or give more reliable data. Clarity of thought and expression separated the stronger candidates from those less prepared to deal with practical situations and the limitations. Candidates should be encouraged to write about four different problems (perhaps relating to the different measurements undertaken or chronologically going through the experiment) stating <u>how</u> these difficulties impact on the experiment. Candidates should then try to think of associated solutions that address each of these problems.

PHYSICS

Paper 9702/35
Advanced Practical Skills 1

Key messages

- In choosing the number of decimal places when recording raw readings, candidates need to relate to the precision of the measuring device, e.g. angles can be read to the nearest degree and lengths (with a ruler) to the nearest millimetre. The number of significant figures in a collection of raw data does not need to be the same (especially when the values range from units to tens) but the number of decimal places must remain the same to reflect the measuring instrument used.

- Calculated values should be rounded correctly to gain credit and not merely truncated.

- Candidates need to use a sharp pencil to draw both plotted points and lines of best fit. Plotted points should be drawn as neat crosses and not as 'blobs' greater than half a square in diameter, and lines should be continuous, thin and straight. A transparent 30 cm ruler should be used for drawing lines of best fit.

- In order to calculate the percentage uncertainty in a measurement, some judgement has to be made about the absolute uncertainty of the measurement. Candidates often just use the precision of the instrument as an indication of the experimental uncertainty in a measurement, but this is often an underestimate of the true uncertainty.

- To be successful answering **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. To practise and develop this skill, either candidates should be encouraged to look at the experiment chronologically stating the limitations as they encounter them, or to focus in on the difficulties of the measurements that are collected.

General comments

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

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

The general standard of the work done by the candidates was good, and there were many excellent scripts. Candidates did not seem to be short of time and both questions were attempted by most 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

(a) (i) Many candidates stated a value for *c* in the appropriate range and with a unit. Some candidates stated a value outside the range or omitted a unit.

(ii) Some candidates stated a value for I in the appropriate range and with a unit. Many candidates stated a value outside the range as the units were inconsistent e.g. 130 A.

(c) Many candidates were able to collect six sets of values of *c* and I without assistance from the Supervisor. Some candidates collected five.

Most candidates kept $c > d$ as requested and some extended their range to $c \geqslant 95.0$ cm. It was expected that candidates make use of the whole metre rule provided.

Some candidates were awarded credit for the column headings, stating the quantity and correct unit. Many candidates added a unit for the $(n + 2)/(n + 1)$ or *n* columns where there should be no unit.

Many candidates correctly recorded their raw values for *c* to the nearest 0.1 cm. Some candidates stated their measurements to the nearest cm without considering that they can make the measurement to the nearest mm using the ruler provided. The number of decimal places in *c* must be consistent down the column to reflect this.

Most candidates calculated $(n + 2)/(n + 1)$ correctly. Some candidates rounded incorrectly or truncated their number instead of rounding.

Overall the table work was done well by candidates. Some candidates either did not have a large enough range in *c* or rounded their measured current to 1 or 2 significant figures; this meant that one or two results overlapped or were identical and so the results did not have the correct trend.

(c) (i) A few candidates omitted labels or marked their scales with gaps that were too large. Compressed scales (i.e. where the points occupy less than half the grid) were often seen and could not be given credit.

There were many awkward scales used by candidates (e.g. based on 3 or 6). A minority of candidates set the minimum and maximum reading in the table to be the minimum and maximum of the graph grid, leading to time-consuming work plotting and using the scales. Awkward scales cannot be awarded credit and it was very common for candidates using such scales to make further mistakes later for incorrect read-offs. A few candidates labelled the scale markings with their point readings from the table or used non-linear scales, and these also cannot be awarded credit. Candidates should be encouraged to set up their graphs to make them easy to work with in later parts of the question.

Some points were drawn as dots with a diameter greater than half a small square ('blobs'). Many points were incorrectly plotted so that they were greater than half a small square from the correct location. If a point seems anomalous, candidates should be encouraged to check the plotting and to repeat the measurement if necessary. If such a point is ignored in assessing the line of best fit, the anomalous point should be labelled clearly e.g. by circling the point (with no more than one point being circled). There is no credit specifically for identifying an anomalous point, so candidates should be reminded that they do not need to identify an anomalous point if they do not think they have one.

(ii) Some candidates were able to draw carefully considered lines of best fit. Others joined the first and last points on the graph or any three points on a straight line regardless of the distribution of the other points. There should always be a balanced distribution of points either side of the line along the entire length. Many lines needed rotation to get a better fit, or an anomalous point needed to be identified to justify the line drawn. Some candidates were not awarded credit because their lines were kinked in the middle, a double line or drawn freehand without the aid of a ruler.

(iii) Some candidates used a suitably large triangle to calculate the gradient, gaining credit for correct read-offs, and substituted into $\Delta y/\Delta x$. Other candidates needed to check that the read-offs used were within half a small square of the line of best fit and show clearly the substitution into $\Delta y/\Delta x$ (not $\Delta x/\Delta y$). Checking the read-offs is especially important when one of the read-offs is on the edge of the grid near a false origin where either x or y is not equal to zero. The equation $m(x - x_1) = (y - y_1)$ should be shown with substitution of read-offs.

Most candidates gained a positive trend and stated that the gradient was positive to reflect this. Candidates need to 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, and many candidates would benefit from double-checking their read-offs.

Many candidates were able to correctly read off the y-intercept at $x = 0$ directly from the graph, but a large number of candidates incorrectly read off the y-intercept when there was a false origin. Some candidates correctly substituted a read-off into $y = mx + c$ to determine the y-intercept. Others needed to check that the point chosen (if it was from the table) was on the line drawn.

(d) Most candidates recognised that S was equal to the gradient and T was equal to the intercept calculated in **(c)(iii)**. Some candidates recorded a value with consistent units for S and T (both mA). Some candidates stated incorrect units or omitted units.

(e) The stronger candidates drew a line for W with a smaller gradient and, as there was often a false origin, a smaller intercept on the page (the intercept would be the same only if there was a true origin i.e. $x = 0$). Many candidates either drew parallel lines, crossed their line with the original line, or drew curved lines.

Question 2

(a) Some candidates stated x and L_1 to the nearest mm and in the appropriate range. Many candidates stated at least one of their values only to the nearest cm. Some candidates stated values that were out of range.

(b) (i) Many candidates measured values of L_2 that were out of range, suggesting that they did not extend the length of the pendulum enough for the periods to be the same.

(ii) Most candidates are familiar with the equation for calculating percentage uncertainty and some gave an uncertainty in L_2 that was suitable for this experiment given the inherent difficulties in taking the measurements involved. Many candidates made too small an estimate of the absolute uncertainty in the value of L_2, typically 0.1 cm or 0.05 cm, or too large an estimate, typically 10.0 cm. Many candidates considered the uncertainty to be the precision of the measuring instrument, yielding an answer that was too small as it did not take into account the difficulties of the experiment. Some candidates repeated their readings and correctly gave the uncertainty in L_2 as half the range.

(iii) Many candidates correctly calculated L_1/L_2. Some candidates truncated their answer instead of rounding correctly.

(iv) Many candidates correctly justified the number of significant figures they had given for the value of L_1/L_2 with reference to the number of significant figures used in L_1 and L_2. Many candidates gave reference to just ‘raw readings’ or ‘values in calculation’ without stating what these values were, or related their significant figures to x as well, which could not be given credit.

(c) Most candidates recorded second values of x, L_1 and L_2. A significant number of candidates recorded a second L_2 value that was greater, suggesting that the experiment had not been carried out correctly.

(d) (i) Most candidates were able to calculate k for the two sets of data, showing their working clearly. A small number of candidates incorrectly rearranged the equation algebraically to calculate $1/k$ or inadvertently substituted the wrong values.

(ii) Some candidates calculated the percentage difference between their two values of k, and then tested it against a specified numerical percentage uncertainty as a criterion, commonly using 10%, 20% or the percentage uncertainty calculated for L_2 in **(b)(ii)**. Many candidates omitted a criterion, or gave a general statement such as 'this is valid because the values are close to each other' or 'strongly supported' without any working, which could not be accepted.

(e) Some candidates calculated l correctly with a consistent unit. Many candidates omitted units, stated an inconsistent unit (e.g. 60.0 m), truncated the number instead of rounding correctly, or gave their final answer to only one significant figure.

(f) Many candidates recognised that two sets of data were insufficient to draw a valid conclusion and stated an improvement of taking more readings and plotting a graph. Some problems stated by candidates correctly related to the measurements taken with a valid reason although there were many identified problems that were not linked to the experiment.

Various reasons for difficulty in measuring the lengths were given, such as having to hold the ruler alongside the string or there being parallax error. To gain credit, the quantity that was difficult to measure should be specified along with the difficulty. Just 'parallax error' or 'parallax error while reading values' on its own without clarification could not be given credit.

Improvements that were common included 'clamp ruler', 'use card gate to release both at the same time' or 'use a spirit level to check the wooden strip is horizontal'. Many candidates correctly drew attention to the fact that it was difficult to see when the oscillations were in phase and the periods matched. Again, clarity is required: the words 'video' or 'spirit level' on their own were not sufficient. A better answer would be 'use a spirit level to check the wooden strip is horizontal' or 'video to see when the periods are the same'.

Credit is not given for suggested improvements that could be carried out in the original experiment, such as 'repeat measurements', 'do more readings to get an average value', 'look perpendicularly onto the ruler', etc. Unrealistic solutions were also not given credit, e.g. 'robotic arm' or 'mechanical hand'. Problems that were irrelevant or that could have been removed if the candidate had taken greater care were not given credit. Vague or generic answers such as 'too few readings' (without stating a consequence), 'faulty apparatus', 'use of a fiducial marker' (as this was not relevant in this experiment) or 'use an assistant' were also not given credit.

The key to this section is for candidates to identify genuine problems associated with setting up this experiment and in obtaining readings. Candidates are then encouraged to suggest practical solutions that either improve technique or give more reliable data. Clarity of thought and expression separated the stronger candidates from those less prepared to deal with practical situations and the limitations. Candidates should be encouraged to write about four different problems (perhaps relating to the different measurements undertaken or chronologically going through the experiment) stating <u>how</u> these difficulties impact on the experiment. Candidates should then try to think of associated solutions that address each of these problems.

PHYSICS

Paper 9702/41
A Level Structured Questions

Key messages

- It is important that candidates use technical language accurately. Examples of words that are often confused by candidates are atom and molecule, nuclide and nucleus, and force and field. Candidates are not able to obtain full credit if they use an inappropriate word that makes the response technically incorrect.

- In defining quantities, candidates need to take care to ensure that the definition they give is dimensionally correct. This often requires use of the phrase 'per unit' where the quantity being defined is the ratio between two other quantities, or 'product' where the quantity being defined is two other quantities being multiplied together.

- Candidates need to be careful that they do not give more than one answer to a question. If multiple answers are provided that are contradictory, the candidate cannot be awarded credit for a correct answer.

- Candidates need to take care to ensure that they read the question properly, understand what is being asked and give responses that answer the question that is asked. It is not uncommon to find candidates giving answers to questions that were not asked, but have been asked in recent past papers. Candidates should be advised not to rely heavily on memorising previous mark schemes.

- When answering questions involving calculations, it is important for candidates to show their reasoning clearly. This includes taking care to use the correct conventional symbols for physical quantities. If working is clear, and based on the use of correct physics, it is often possible to receive some credit even when the final answer is incorrect.

General comments

Candidates managed their time well with little evidence of candidates not being able to complete the paper.

Descriptive questions proved to be much more difficult for candidates than calculations. When answering with explanations, candidates need to take care to use the correct technical terms and avoid ambiguity. Many candidates are better at recalling information learnt by heart than at applying principles to new situations. Diagrams and graphs also caused some difficulties for candidates, and many candidates would benefit from taking more care when using them.

Candidates need to follow the instructions given in questions, use the symbols given, and add labels as directed. Examples of this are Questions **1(a)**, **6(c)**, **8(a)(ii)** and **8(b)(ii)**.

It would be advisable for candidates to remember to convert to standard units before embarking on calculations. Examples of this were conversions from cm^3 to m^3 in **Question 2**, cm^2 to m^2 in **Question 3** and u to kg in **Question 11**.

Comments on specific questions

Question 1

(a) This question was well answered by many candidates. Some did not state the name of the extra symbol used, which was *G*. Some candidates used *r* instead of *x* and explained that this was 'radius', which is incorrect here as it should be the separation of the two masses.

(b) (i) This question was also well answered and usually well presented. Candidates need to show full substitution in 'show that' questions which includes constants such as *G*. A small but significant number of candidates just used the height above the surface of the planet and forgot to add the radius to this number. Some others started with incorrect physics and tried to apply energy ideas such as $½mv^2 = GMm/x^2$, which did not lead to the correct answer.

(ii) Again, this calculation was generally well answered. Some candidates made an error by thinking that $\left(\frac{1}{r_2 - r_1}\right)$ was the same mathematically as $\left(\frac{1}{r_2} - \frac{1}{r_1}\right)$.

(c) Many candidates incorrectly applied conservation of energy here and had one energy type increasing while the other was decreasing. They did not look at the context of the question which gave the speed of the spacecraft in the two locations. Candidates should be aware that the gravitational potential energy of the spacecraft would decrease as it approached the planet. A few candidates referred to gravitational potential when they really meant gravitational potential energy.

Question 2

(a) (i) This calculation was well carried out with a few power-of-ten errors caused by incorrect or missing conversions from cm^3 to m^3. A small number of candidates were unsure of the meaning of 'amount of gas' and calculated the number of molecules instead. Some candidates quoted the answer to only one significant figure.

(ii) This calculation was also completed well. Roughly equal numbers of candidates used $V \propto T$ and $pV = nRT$.

(iii) Most candidates calculated this correctly. There were a few power-of-ten errors again as in **(a)(i)**.

(b) Many candidates did not realise that the heat transfer was negative. As work is being done on the gas and its temperature is decreasing, thermal energy must be transferred *from* the gas, so *q* is negative. Most candidates just added the work done to the thermal energy.

Question 3

(a) (i) There was a large range of answers to this straightforward question. Incorrect answers included 2 m, 0.04 m and 0.06 m.

(ii) This calculation was well answered.

(iii) Many candidates answered this question correctly.

(b) Most candidates were able to correctly manipulate the given equation in order to find the density of the liquid. There were some errors caused by incorrect conversion from cm^2 to m^2 and also from incorrect squaring of the 2 and the π.

(c) Some candidates could not be awarded credit because of a lack of care over drawing. The amplitude of the oscillation at every crest/trough becomes progressively smaller, and the period should stay the same or slightly increase. Some candidates decreased the amplitude of the peaks but did not change the amplitude of the troughs.

Question 4

(a) (i) This question was well answered. Some candidates were not awarded credit because of the use of words such as energy (which is time-dependent) and strength (which is too vague) rather than power/amplitude/intensity.

(ii) Many candidates were awarded partial credit. The word 'interference' has a specific meaning in physics and should not be used in reference to noise. Some candidates also confused 'noise' with 'sound'.

(b) This was generally well answered. A common error was to write that digital signals have less noise which is incorrect. The advantage is that the noise can be removed.

(c) (i) This was also generally well answered. Some candidates omitted this part, perhaps because there was no answer space. It is worth reminding candidates that they can look for the marks in square brackets on the right-hand side to ensure they have not missed a question.

(ii) Candidates who knew how to convert from decimal to binary generally received full credit.

(d) Most candidates were successful. Candidates should be careful not to add construction lines to their diagrams if these can easily be confused with the intended answer. It is not possible to award credit if there are two contradictory answers.

Question 5

(a) In a definition like this, candidates need to make sure that the idea of the division is clear, for example 'per unit charge'. The fact that electric field strength is defined in terms of positive charge was not well known.

(b) (i) A common response to this question was that the charges had opposite sign because the line went from positive to negative. Candidates needed to think about the direction of the electric field lines and remember that electric field strength is a vector quantity.

(ii) Many stronger candidates answered this well. Some candidates did not realise that the field from B would affect the shape of the graph as it was showing the resultant electric field strength due to both charges.

(iii) Candidates found this question challenging. They often did not realise the significance of the point where the resultant electric field strength was zero. Many candidates incorrectly picked a point near to charge A and a point near to charge B and used $Q = 4\pi\varepsilon_0 r^2 E$ to find each charge and hence the ratio. This approach does not work as the line on the graph is due to both charges, not just one.

Question 6

(a) Most candidates were able to give two functions of capacitors in electrical circuits.

(b) Many candidates gained full credit for this derivation.

(c) Although many candidates could work out the answers to this question, candidates needed to ensure that they drew the diagrams accurately. They should make sure that they draw a capacitor with two equal length straight lines and a cell with two lines of different lengths, so that the two symbols are not confused. Also, if they do not show a cell, they should make sure that it is clear how the capacitors would be connected to the external circuit. If this is not done, the diagram is ambiguous and it is not possible to award credit.

Question 7

(a) (i) This was generally well answered. Some candidates forgot to mention the gain of the amplifier.

(ii) Many candidates achieved the correct magnitude of the gain but did not gain full credit because they omitted the minus sign. A few candidates started with the incorrect gain formula for this type of amplifier.

(b) Most candidates calculated the resistance of the diode and stopped there. They did not appreciate that the output of 5.0 V would be shared between the resistor and the diode and hence there was (5.0 – 2.3) = 2.7 V across the resistor.

Question 8

(a) (i) A field is a region where a force is felt. In the case of a magnetic field, the force can be felt by several different things. Candidates should be careful not to try to list all of the possibilities, as this can lead to candidates contradicting themselves.

(ii) Most arrows were in the correct direction. Some arrows were not in the required location, including positions where the field was not downwards, and these could not gain credit.

(b) (i) The word 'direction' is essential in this explanation when referring to the induced e.m.f. For the second part of the explanation ('oppose the change producing it') the key word is 'oppose'. Some weaker candidates wrote 'in the opposite direction' here. Phrases such as 'the current flows in the opposite direction to the change producing it' which confuse the two parts of the explanation could not gain credit.

(ii) Many candidates repeated Lenz's law here rather than applying it to the given situation. Some candidates correctly stated the direction of the field but did not draw an arrow in the diagram. The idea that an e.m.f. is induced when the field is *changing* (in this case increasing) was often omitted. Weaker candidates suggested that the current in the small coil would be constant as long as the switch in the solenoid was closed.

(c) This was generally well answered. Many candidates did not realise that reversing the current would give a total change in flux density of 2.8 mT.

Question 9

(a) This question about nuclear magnetic resonance imaging was more structured than some questions on the topic. Candidates who had learnt mark schemes by rote found it difficult to apply what they knew and included a large amount of irrelevant detail. Many candidates knew that precession was important, but some referred to atoms or molecules instead of nuclei or protons.

(b) Many candidates knew that the non-uniform field was used to locate the position of the nuclei.

Question 10

(a) Many candidates were able to interpret the equation for the variation if the input e.m.f. in order to state the maximum p.d. across the resistor. Some candidates multiplied or divided by $\sqrt{2}$ as they were unsure of peak and r.m.s. values.

(b) This calculation proved to be challenging. Candidates found it difficult identify the value of ω from the equation to determine the time period. Some of those who did manage this then multiplied by 4 instead of 2 in order to find the time duration required by the question. Other common errors were to use degrees instead of radians and to quote the final answer to just one significant figure.

Question 11

(a) Many answers here were incomplete. Candidates often forgot to mention electrons or wrote about the number of electrons rather than the rate of emission of electrons. There were some who mixed up electrons and photons and referred to the emission of photons.

(b) (i) Most candidates knew the correct formulae to use and this calculation was completed well. Only a small number of candidates stopped when they obtained the energy in J rather than converting to eV.

(ii) The majority of candidates chose the correct metals here, but did not always relate their choice to the work function energy being less that the energy of the photon. A small but significant number of candidates chose the incorrect two metals because they thought the work function would need to be greater than the photon energy.

(c) Some candidates completed this challenging calculation well. Some candidates found the momentum of the photon, but then divided by (rather than multiplying by) the rate of emission of photons. Weaker candidates often did not know where to begin, as they were not familiar with the idea of photons having momentum and so exerting a force when incident on a surface.

Question 12

(a) Candidates found all parts of this question difficult. Many candidates quoted known formulae for activity or the decay constant λ in terms of half-life or other variables rather than those asked for, suggesting that they did not understand the fundamental definitions of these quantities.

(b) (i) 1. Most candidates were able to calculate the change in mass, but did not quote their answer to enough significant figures. It is important not to round answers prematurely in this type of question because the differences in mass are very small.

2. Many candidates answered this question successfully. A common error was to forget to convert from mass in u to mass in kg.

(ii) Most candidates were able to gain partial credit here. Weaker candidates often quoted energy changes learnt by rote, e.g. sound and heat. Some responses were too vague to be given credit, e.g. ‘kinetic energy of products’ or ‘emission of radiation’.

PHYSICS

Paper 9702/42
A Level Structured Questions

Key messages

- It is important that candidates use technical language accurately. Examples of words that are often confused by candidates are atom and molecule, nuclide and nucleus, and force and field. Candidates are not able to obtain full credit if they use an inappropriate word that makes the response technically incorrect.

- In defining quantities, candidates need to take care to ensure that the definition they give is dimensionally correct. This often requires use of the phrase 'per unit' where the quantity being defined is the ratio between two other quantities, or 'product' where the quantity being defined is two other quantities being multiplied together.

- Candidates need to be careful that they do not give more than one answer to a question. If multiple answers are provided that are contradictory, the candidate cannot be awarded credit for a correct answer.

- Candidates need to take care to ensure that they read the question properly, understand what is being asked and give responses that answer the question that is asked. It is not uncommon to find candidates giving answers to questions that were not asked, but have been asked in recent past papers. Candidates should be advised not to rely heavily on memorising previous mark schemes.

- When answering questions involving calculations, it is important for candidates to show their reasoning clearly. This includes taking care to use the correct conventional symbols for physical quantities. If working is clear, and based on the use of correct physics, it is often possible to receive some credit even when the final answer is incorrect.

General comments

The question paper contained questions of a variety of levels of difficulty, enabling candidates at different levels of ability to show what they know. Candidates who knew the 'bookwork', read the questions carefully, took care over their use of technical language and answered the questions asked were able to perform well.

There was no evidence that candidates had insufficient time in which to complete the paper. However, it was not uncommon for candidates to omit the occasional part-question. Candidates should be advised that it is always worth offering a response to each part-question; no credit can be obtained where a question has been omitted, but if a response is attempted then it may be possible to be award partial credit.

Significant figures were more problematic for candidates this series than in some other recent series. It was common for candidates to give answers to fewer significant figures than were supported by the information in the question. A related issue concerns premature rounding within a question. An intermediate value that is calculated within a question should be carried with more significant figures than will be given in the final answer; rounding too early carries the risk of introducing arithmetic errors into the final answer. Candidates should be made aware that giving answers to too few significant figures or rounding intermediate answers prematurely can both lead to incorrect final answers that cannot be given full credit.

Comments on specific questions

Question 1

(a) This question was mostly well answered. Some candidates chose to use a letter, other than the one that was given in the question, for the separation of the masses. These candidates could still gain full credit provided they defined the letter correctly. Common errors were to use *r* for *x* but then either not define it or define it as 'radius', to omit to state the name of *G*, or to forget to square *x* in the denominator.

(b) (i) Most candidates knew the relationship between arc length, radius and angle in radians, and were able to show where the 0.015 radian angle comes from very straightforwardly. A common reason for not being awarded credit was to treat the sector of the circle as a triangle and hence incorrectly attempt to introduce trigonometric relationships.

(ii) Most candidates were able to use the angle given in **(b)(i)** in the given expression to reach the correct answer.

(c) (i) Candidates were told, in the question, to equate the torque in **(b)(ii)** with the *moment* of the gravitational force about the thread. A large proportion of candidates equated the force with the torque and were therefore unable to be awarded credit. Another common incorrect starting point was use of the distance between the spheres (instead of the distance between S and the thread) when calculating the moment of the gravitational force. Most candidates who started with the correct moments expression were able to go on to receive credit.

(ii) Candidates found this question difficult. Many candidates missed the fact that the question was asking about the force *between* the spheres, not about other forces that may be exerted on each sphere individually. Common responses that were not awarded credit referred to air resistance (the system is static), torsion in the thread (already in consideration) and gravitational attraction to the Earth (not a force between the spheres). These responses illustrate the importance of reading the question carefully and answering the question that is asked.

Question 2

(a) (i) Most candidates appeared to know that *q* is something to do with thermal energy, and *w* is something to do with work, but it is not possible to address the significance of those quantities being positive without being clear which way the energy is being transferred into or out of the system. This is why the question made specific reference to the 'system'. Where the direction of energy transfer was ambiguous (such as 'thermal energy in the system') or contradictory (such as 'work done on/by the system'), it was not possible to award credit.

(ii) This question was successfully answered by many candidates. Common mistakes were to omit to make clear that the change in energy is of <u>internal</u> energy or to omit to refer to a change. A common incorrect answer was 'the internal energy is negative'. Other candidates attempted to answer a question asking about how the internal energy can decrease (by discussing various permutations of thermal energy being emitted by the system and work being done by the system). The question that was asked, about the meaning of a negative value of ΔU, has only one answer, and candidates who gave contradictory answers could not be awarded credit.

(b) (i) Some candidates misread the question and, instead of answering about the total change over one complete cycle, discussed the changes involved in the individual steps all the way around the cycle. All that candidates were expected to do was to observe that the initial and final temperatures are the same, and hence the net change in internal energy around a full cycle is zero.

(ii) This question was generally well answered, with most candidates successfully substituting the correct values into $W = p\Delta V$.

(iii) Some candidates missed the units in the column headings and did not realise that the question was asking for numerical values in the table. These candidates just indicated increases and decreases, which was not what was required. Many candidates did complete the table successfully and were awarded full credit. For full credit, candidates needed to realise that the work calculated in **(b)(ii)** is negative, and to calculate $+q$ accordingly. This was the most common reason for credit not being awarded, although some candidates also did not appreciate that the ΔU column had to add up to zero.

Question 3

(a) Most candidates had little difficulty with **(i)**, but **(ii)** required them to appreciate that maximum elastic potential energy occurs when the spring is at its longest. Accordingly, 0.2 s was a common incorrect answer to this part.

(b) (i) Most candidates knew how to calculate angular frequency from period and to substitute in the correct value. An answer of '5π' was common; candidates should calculate their answers and to express them to an appropriate number of significant figures, so candidates should be encouraged not to leave answers as multiples of π unless the question asks them to do so.

(ii) Credit was available for quoting the correct starting equation $v_0 = \omega x_0$. If this is not written down correctly (e.g. with omission of the indication of peak values) then credit can be awarded by implication if the substituted values show that the correct equation was used. This was often not possible here because the correct substituted values were not used. A common error was to use 14.5 cm as the amplitude of the oscillation.

(iii) As in **(b)(ii)**, more care over writing down at least the starting equation correctly would have been advantageous to many candidates.

(c) Many candidates were able correctly to deduce that the period of oscillation decreases, but comparatively few gave a convincing reason to explain their conclusion. Many candidates confused amplitude of oscillation with the fact that there is a new equilibrium position, and did not appreciate that the amplitude of the oscillations is unconnected to the number of springs used.

Question 4

(a) This was generally well answered. Most candidates were able to state that specific acoustic impedance is the product of density and speed, although clarifying which speed proved a little more problematic for some. Many weaker candidates thought that the speed was the speed of light.

(b) This was an example of the need to answer the question that was asked, and not another question that may have been asked in a previous paper that looks a little similar. This question was asking for comment on a ratio, not a qualitative observation about amounts of transmission. Also, the question asks about the ratio of the *transmitted* intensity to the incident intensity. Many candidates gave responses in which they were clearly talking about the ratio of *reflected* intensity to the incident intensity. Candidates who read the question carefully, and answered the question asked, often answered it well.

(c) This question was generally well answered, with many candidates being awarded full credit.

Question 5

(a) (i) Most candidates stated correctly that attenuation is the loss of power from a signal. Energy was not, in itself, a quantity that was given credit, because in the context of transmission of a signal, energy is a time-dependent quantity and, in the absence of any reference to time, is rather meaningless.

(ii) Candidates were expected to state that noise is unwanted power that is added to the signal being transmitted. Various alternative forms of words that conveyed the same ideas were accepted. Some candidates phrased their responses in terms of sound and this could not be awarded credit. Others wrote about 'interference'. It is important for candidates to understand that they must use technical syllabus terminology correctly. In this case, use of the word 'interference' in the context of noise in a signal is not the correct use of a technical term.

(b) (i) Most candidates knew the definition of attenuation in terms of the logarithm of the ratio of two powers, and many were able to substitute values to arrive at an attenuation per unit length that had the correct magnitude. A substantial minority of candidates substituted the powers the wrong way round, leading to an answer that either was negative, or should have been negative had the arithmetic been performed correctly. Having made this type of mistake, candidates should not ignore minus signs in answers, but to consider whether the substitution of the powers was correct in the initial expression.

(ii) Many candidates were awarded full credit here. Common errors were to use the reciprocal of the power ratio or to use the 2.5 mW figure as the input power to the amplifier.

Question 6

(a) Candidates needed to give a dimensionally correct definition for the magnitude of electric potential, as a work done per unit charge. Many candidates did not do this, and instead gave definitions that had the dimensions of energy rather than potential. More candidates received credit for giving a definition that yielded the correct sign, most commonly by referring to the work done in moving positive charge from infinity.

(b) Candidates were expected to realise that the potential is V_0 when $x = 0$, 0 when $x = d$, and varies linearly in between. Many candidates did not appreciate that the potential gradient between two parallel plates is constant.

(c) Many candidates were awarded at least partial credit. Most candidates realised that the magnitudes of the potentials at the surfaces of the spheres were the same. Comparatively few candidates appreciated that the potential remains constant inside the sphere. For the region between the two surfaces, many candidates drew the variation of electric field strength rather than electric potential.

Question 7

(a) Many candidates were able to receive partial credit, and stronger candidates achieved full credit. There were some common misconceptions. Firstly, the question was asking about variation of resistance with temperature, not variation with light intensity. Candidates who started by discussing electrons absorbing photons had not read the question properly. Secondly, a significant number of candidates wrote that a decrease in resistance is caused by an increase in current (rather than being the cause of the increase in current). Thirdly, some candidates have a misconception that electrons ‘moving’ (from one band to the other) create the current in the semiconductor. And fourthly, for those candidates who did appreciate that decreased resistance is caused by an increase in the number of charge carriers, the phrasing of that concept was often imprecise. For example, responses often conveyed that the charge carriers had ‘more charge’, or ‘a greater density’.

(b) Many candidates found this question straightforward and were awarded full credit. Candidates needed to read the 2.55 kΩ resistance at 10 °C off the graph. They then had to put that into the potential divider relationship to deduce the output p.d. of 1.58 V – a common error here was to calculate a current at the initial temperature and then assume that this current remained the same when the temperature changed, which led to a common incorrect answer of 0.7 V.

Candidates also needed to subtract the output p.d. from 1.00 V and give the difference to 2 significant figures. Both aspects of this point proved to be difficult for some candidates. Candidates should be advised that, when a question specifies a particular number of significant figures to which an answer should be given, then the answer will not be awarded credit if it is given to a different number of significant figures.

(c) This was a difficult question, and many weaker candidates gave responses that re-stated the question. Candidates needed to explain that neither the variation of resistance with temperature for a thermistor, nor the variation of p.d. with resistance for a resistor in a potential divider, are linear.

Question 8

(a) (i) This question was generally well answered. A common incorrect response arose from confusing sine and cosine, to get an answer of $2.9 \times 10^{7}\,\mathrm{m\,s^{-1}}$.

(ii) Most candidates knew that the starting point for answering this question was to equate Bqv with mv^2 / r to get the expression for the radius $r = mv / Bq$. Many candidates did not appreciate that the value of v to be used in this expression is the component that is perpendicular to the magnetic field that they had already calculated in **(a)(i)**. As a result, there were attempts to insert unnecessary trigonometric factors on both sides of the equation. Of the candidates who calculated the answer correctly, some chose to give their answer to an unjustifiably low number of significant figures.

(b) Only the stronger candidates realised that the magnetic force acting on a charged particle moving parallel to a magnetic field is zero.

(c) Correct answers to this question were rare. Many candidates simply described the motion of the electron as circular. A small number of candidates correctly described the motion as helical, but candidates could also gain credit without the use of the word, if they described the motion in two components (circular motion in one plane, and linear motion in the third direction).

Question 9

(a) (i) Candidates needed to show a coil connected across the left-hand terminals and a switch connected across the right-hand terminals. Candidates who connected the lamp terminals to the amplifier terminals could not receive credit.

(ii) Many candidates correctly decided that the output had to be negative, but found it difficult to explain this. Incorrect use of the phrase 'reverse biased' was common, and few candidates demonstrated an understanding of what this means. Many candidates described voltages (or outputs) 'flowing', and others simply described the orientation of the diode in the circuit.

(b) (i) Most candidates realised that the required transducer was a strain gauge, although a significant minority of candidates named a thermistor.

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

Question 10

(a) This was well answered by a significant majority of candidates. This is a commonly-asked question, and candidates on the whole know Faraday's law well. Of those who did not achieve full credit, common mistakes were to omit all or part of 'rate of change'. Some candidates confused e.m.f. and current; Faraday's law does not give any indication about any current that might flow as a result of the induced e.m.f. (that current being determined by the magnitude of the e.m.f. and the resistance of the circuit).

(b) Candidates find it difficult to use the correct terminology when describing electromagnetic effects in circuits. Candidates were expected to comment that the current in the primary coil creates a magnetic field; some candidates gave responses that conveyed that this only happens when the current varies. Candidates also needed to describe the role of the soft-iron core in linking the changing flux in the primary with the changing flux in the secondary. There were some misconceptions about the role of the core, including having an e.m.f. induced in it, and it conducting current from the primary to the secondary coil. Candidates also needed to demonstrate an understanding that the current in the resistor is caused by the induced e.m.f. in the secondary coil. A common misconception here was that the current is what is induced by the changing flux.

(c) Many candidates were unsure of how to deal with the sinusoidal function and found the question difficult. Candidates needed to see that 220 V is the peak input voltage, and then to apply the turns ratio and r.m.s. conversion to this (in either order) to get an answer of 25.9 V. In very many cases, candidates put some value of time into the sinusoidal expression and worked out a voltage. Candidates who adopted this approach could not be awarded any credit.

Question 11

(a) Most candidates correctly identified a photon as a quantum of energy. Fewer candidates mentioned that this energy is electromagnetic in nature. Many candidates stated that electromagnetic radiation 'carries' or 'emits' photons, rather than appreciating that the photons *are* the electromagnetic radiation.

(b) (i) This question was generally well answered by most candidates. This was another question in which candidates often stated an answer to fewer significant figures than are supported by the data in the question.

(ii) This question was also well answered by many candidates. Some made errors with the power of ten in the answer.

(c) This is another question that was well answered by most candidates, provided they realised that they just needed to apply $p = mv$ to a particle with a given momentum and a mass of 60 u. Candidates who incorrectly used the relationship between energy and momentum for a photon obtained the speed of light for their answer. Candidates should be encouraged to consider the plausibility of their answers, and an answer of the speed of light for the speed of a nucleus should serve as an instant clue that a mistake has been made.

Question 12

(a) Candidates must be careful when using technical syllabus terminology. Allowance cannot be made for a candidate's English if a technical word is used incorrectly in a way that can be confused with another technical word. An example of this is the words nucleus, nuclei, nuclide, neutron, nucleon and nucleons. These are technical terms that mean different things and that candidates need to use correctly.

In this question, candidates were expected to define binding energy as the energy required to separate the nucleons (in a nucleus) from each other, to an infinite distance. Misuse of the correct terminology (for example, by separating a single nucleon from the nucleus, or by splitting nuclei) resulted in it not being possible to award credit. A small number of candidates misread the question and gave a definition of binding energy per nucleon.

(b) Many candidates answered this question correctly and were awarded full credit. The first stage was to calculate the mass defect in u. Most candidates did this successfully, although some candidates confused the number of protons and number of neutrons, and other candidates included 141 masses of lanthanum-141 in their mass defect calculation.

Provided a mass defect was clearly calculated, credit was then given for the correct conversion of a mass defect into the equivalent energy in joules. The majority of candidates were awarded credit for stating $E = mc^2$; common errors in applying it were to forget to square the value of c and to forget to convert the mass from u to kg before applying the energy conversion.

(c) (i) Candidates who knew the correct starting equations (or who were able to extract the correct equations from the formula sheet) were usually able to go on to correctly calculate the required time. This question is an example of the danger of rounding intermediate values, as this sometimes resulted in an incorrect answer of 5.1 hours. Numerical answers are expected to be correct to the number of significant figures being dealt with in the question (in this case, two), and premature rounding can make an answer incorrect to the number of significant figures expected.

(ii) Most candidates did not pay adequate attention to what the question was asking, and wrote 'background radiation' as if a standard answer to this type of question. Stronger candidates who read the question properly realised that it was asking about the *activity* of the sample and not a measured count rate. Background radiation has no connection to the rate at which the *sample* emits ionising radiation.

PHYSICS

Paper 9702/43
A Level Structured Questions

Key messages

- It is important that candidates use technical language accurately. Examples of words that are often confused by candidates are atom and molecule, nuclide and nucleus, and force and field. Candidates are not able to obtain full credit if they use an inappropriate word that makes the response technically incorrect.
- In defining quantities, candidates need to take care to ensure that the definition they give is dimensionally correct. This often requires use of the phrase 'per unit' where the quantity being defined is the ratio between two other quantities, or 'product' where the quantity being defined is two other quantities being multiplied together.
- Candidates need to be careful that they do not give more than one answer to a question. If multiple answers are provided that are contradictory, the candidate cannot be awarded credit for a correct answer.
- Candidates need to take care to ensure that they read the question properly, understand what is being asked and give responses that answer the question that is asked. It is not uncommon to find candidates giving answers to questions that were not asked, but have been asked in recent past papers. Candidates should be advised not to rely heavily on memorising previous mark schemes.
- When answering questions involving calculations, it is important for candidates to show their reasoning clearly. This includes taking care to use the correct conventional symbols for physical quantities. If working is clear, and based on the use of correct physics, it is often possible to receive some credit even when the final answer is incorrect.

General comments

Candidates managed their time well with little evidence of candidates not being able to complete the paper.

Descriptive questions proved to be much more difficult for candidates than calculations. When answering with explanations, candidates need to take care to use the correct technical terms and avoid ambiguity. Many candidates are better at recalling information learnt by heart than at applying principles to new situations. Diagrams and graphs also caused some difficulties for candidates, and many candidates would benefit from taking more care when using them.

Candidates need to follow the instructions given in questions, use the symbols given, and add labels as directed. Examples of this are Questions **1(a)**, **6(c)**, **8(a)(ii)** and **8(b)(ii)**.

It would be advisable for candidates to remember to convert to standard units before embarking on calculations. Examples of this were conversions from cm^3 to m^3 in **Question 2**, cm^2 to m^2 in **Question 3** and u to kg in **Question 11**.

Comments on specific questions

Question 1

(a) This question was well answered by many candidates. Some did not state the name of the extra symbol used, which was *G*. Some candidates used *r* instead of *x* and explained that this was 'radius', which is incorrect here as it should be the separation of the two masses.

(b) (i) This question was also well answered and usually well presented. Candidates need to show full substitution in 'show that' questions which includes constants such as *G*. A small but significant number of candidates just used the height above the surface of the planet and forgot to add the radius to this number. Some others started with incorrect physics and tried to apply energy ideas such as $\frac{1}{2}mv^2 = GMm/x^2$, which did not lead to the correct answer.

(ii) Again, this calculation was generally well answered. Some candidates made an error by thinking that $\left(\frac{1}{r_2 - r_1}\right)$ was the same mathematically as $\left(\frac{1}{r_2} - \frac{1}{r_1}\right)$.

(c) Many candidates incorrectly applied conservation of energy here and had one energy type increasing while the other was decreasing. They did not look at the context of the question which gave the speed of the spacecraft in the two locations. Candidates should be aware that the gravitational potential energy of the spacecraft would decrease as it approached the planet. A few candidates referred to gravitational potential when they really meant gravitational potential energy.

Question 2

(a) (i) This calculation was well carried out with a few power-of-ten errors caused by incorrect or missing conversions from cm^3 to m^3. A small number of candidates were unsure of the meaning of 'amount of gas' and calculated the number of molecules instead. Some candidates quoted the answer to only one significant figure.

(ii) This calculation was also completed well. Roughly equal numbers of candidates used $V \propto T$ and $pV = nRT$.

(iii) Most candidates calculated this correctly. There were a few power-of-ten errors again as in **(a)(i)**.

(b) Many candidates did not realise that the heat transfer was negative. As work is being done on the gas and its temperature is decreasing, thermal energy must be transferred *from* the gas, so *q* is negative. Most candidates just added the work done to the thermal energy.

Question 3

(a) (i) There was a large range of answers to this straightforward question. Incorrect answers included 2 m, 0.04 m and 0.06 m.

(ii) This calculation was well answered.

(iii) Many candidates answered this question correctly.

(b) Most candidates were able to correctly manipulate the given equation in order to find the density of the liquid. There were some errors caused by incorrect conversion from cm^2 to m^2 and also from incorrect squaring of the 2 and the π.

(c) Some candidates could not be awarded credit because of a lack of care over drawing. The amplitude of the oscillation at every crest/trough becomes progressively smaller, and the period should stay the same or slightly increase. Some candidates decreased the amplitude of the peaks but did not change the amplitude of the troughs.

Question 4

(a) (i) This question was well answered. Some candidates were not awarded credit because of the use of words such as energy (which is time-dependent) and strength (which is too vague) rather than power/amplitude/intensity.

(ii) Many candidates were awarded partial credit. The word 'interference' has a specific meaning in physics and should not be used in reference to noise. Some candidates also confused 'noise' with 'sound'.

(b) This was generally well answered. A common error was to write that digital signals have less noise which is incorrect. The advantage is that the noise can be removed.

(c) (i) This was also generally well answered. Some candidates omitted this part, perhaps because there was no answer space. It is worth reminding candidates that they can look for the marks in square brackets on the right-hand side to ensure they have not missed a question.

(ii) Candidates who knew how to convert from decimal to binary generally received full credit.

(d) Most candidates were successful. Candidates should be careful not to add construction lines to their diagrams if these can easily be confused with the intended answer. It is not possible to award credit if there are two contradictory answers.

Question 5

(a) In a definition like this, candidates need to make sure that the idea of the division is clear, for example 'per unit charge'. The fact that electric field strength is defined in terms of positive charge was not well known.

(b) (i) A common response to this question was that the charges had opposite sign because the line went from positive to negative. Candidates needed to think about the direction of the electric field lines and remember that electric field strength is a vector quantity.

(ii) Many stronger candidates answered this well. Some candidates did not realise that the field from B would affect the shape of the graph as it was showing the resultant electric field strength due to both charges.

(iii) Candidates found this question challenging. They often did not realise the significance of the point where the resultant electric field strength was zero. Many candidates incorrectly picked a point near to charge A and a point near to charge B and used $Q = 4\pi\varepsilon_0 r^2 E$ to find each charge and hence the ratio. This approach does not work as the line on the graph is due to both charges, not just one.

Question 6

(a) Most candidates were able to give two functions of capacitors in electrical circuits.

(b) Many candidates gained full credit for this derivation.

(c) Although many candidates could work out the answers to this question, candidates needed to ensure that they drew the diagrams accurately. They should make sure that they draw a capacitor with two equal length straight lines and a cell with two lines of different lengths, so that the two symbols are not confused. Also, if they do not show a cell, they should make sure that it is clear how the capacitors would be connected to the external circuit. If this is not done, the diagram is ambiguous and it is not possible to award credit.

Question 7

(a) (i) This was generally well answered. Some candidates forgot to mention the gain of the amplifier.

(ii) Many candidates achieved the correct magnitude of the gain but did not gain full credit because they omitted the minus sign. A few candidates started with the incorrect gain formula for this type of amplifier.

(b) Most candidates calculated the resistance of the diode and stopped there. They did not appreciate that the output of 5.0 V would be shared between the resistor and the diode and hence there was (5.0 – 2.3) = 2.7 V across the resistor.

Question 8

(a) (i) A field is a region where a force is felt. In the case of a magnetic field, the force can be felt by several different things. Candidates should be careful not to try to list all of the possibilities, as this can lead to candidates contradicting themselves.

(ii) Most arrows were in the correct direction. Some arrows were not in the required location, including positions where the field was not downwards, and these could not gain credit.

(b) (i) The word 'direction' is essential in this explanation when referring to the induced e.m.f. For the second part of the explanation ('oppose the change producing it') the key word is 'oppose'. Some weaker candidates wrote 'in the opposite direction' here. Phrases such as 'the current flows in the opposite direction to the change producing it' which confuse the two parts of the explanation could not gain credit.

(ii) Many candidates repeated Lenz's law here rather than applying it to the given situation. Some candidates correctly stated the direction of the field but did not draw an arrow in the diagram. The idea that an e.m.f. is induced when the field is *changing* (in this case increasing) was often omitted. Weaker candidates suggested that the current in the small coil would be constant as long as the switch in the solenoid was closed.

(c) This was generally well answered. Many candidates did not realise that reversing the current would give a total change in flux density of 2.8 mT.

Question 9

(a) This question about nuclear magnetic resonance imaging was more structured than some questions on the topic. Candidates who had learnt mark schemes by rote found it difficult to apply what they knew and included a large amount of irrelevant detail. Many candidates knew that precession was important, but some referred to atoms or molecules instead of nuclei or protons.

(b) Many candidates knew that the non-uniform field was used to locate the position of the nuclei.

Question 10

(a) Many candidates were able to interpret the equation for the variation if the input e.m.f. in order to state the maximum p.d. across the resistor. Some candidates multiplied or divided by √2 as they were unsure of peak and r.m.s. values.

(b) This calculation proved to be challenging. Candidates found it difficult identify the value of ω from the equation to determine the time period. Some of those who did manage this then multiplied by 4 instead of 2 in order to find the time duration required by the question. Other common errors were to use degrees instead of radians and to quote the final answer to just one significant figure.

Question 11

(a) Many answers here were incomplete. Candidates often forgot to mention electrons or wrote about the number of electrons rather than the rate of emission of electrons. There were some who mixed up electrons and photons and referred to the emission of photons.

(b) (i) Most candidates knew the correct formulae to use and this calculation was completed well. Only a small number of candidates stopped when they obtained the energy in J rather than converting to eV.

(ii) The majority of candidates chose the correct metals here, but did not always relate their choice to the work function energy being less that the energy of the photon. A small but significant number of candidates chose the incorrect two metals because they thought the work function would need to be greater than the photon energy.

(c) Some candidates completed this challenging calculation well. Some candidates found the momentum of the photon, but then divided by (rather than multiplying by) the rate of emission of photons. Weaker candidates often did not know where to begin, as they were not familiar with the idea of photons having momentum and so exerting a force when incident on a surface.

Question 12

(a) Candidates found all parts of this question difficult. Many candidates quoted known formulae for activity or the decay constant λ in terms of half-life or other variables rather than those asked for, suggesting that they did not understand the fundamental definitions of these quantities.

(b) (i) 1. Most candidates were able to calculate the change in mass, but did not quote their answer to enough significant figures. It is important not to round answers prematurely in this type of question because the differences in mass are very small.

2. Many candidates answered this question successfully. A common error was to forget to convert from mass in u to mass in kg.

(ii) Most candidates were able to gain partial credit here. Weaker candidates often quoted energy changes learnt by rote, e.g. sound and heat. Some responses were too vague to be given credit, e.g. ‘kinetic energy of products’ or ‘emission of radiation’.

PHYSICS

Paper 9702/51
Planning, Analysis and Evaluation

Key messages

- Candidates should be encouraged to read all the questions carefully before answering them to understand what is required.
- Planning a few key points before answering **Question 1** is useful.
- In **Question 1**, candidates' responses should include detailed explanations of experimental procedures such as how to control variables, how to take measurements and how to analyse the data.
- Graphical work should be carefully attempted and checked. Care is also needed when reading information from the graph.
- The numerical answers towards the end of **Question 2** require candidates to show all their working particularly when determining uncertainties. A full understanding of significant figures and the treatment of uncertainties is required. In particular, candidates must be aware of the differences between absolute uncertainties and percentage uncertainties.
- The practical skills required for this paper should be developed and practised with a 'hands on' approach throughout the course.

General comments

In **Question 1**, it is advisable that candidates should think carefully about the experiment following the points given on the question paper and to imagine how they would perform the experiment in the laboratory. There were some unworkable setups shown in diagrams and often some important measurements were omitted. Many candidates were successful in the analysis section with clear identification of how the constants could be determined. Many candidates did not provide enough additional detail. It is essential for candidates to have experienced practical work in preparation for answering this paper.

In **Question 2**, candidates should be familiar with completing a results table for quantities and their uncertainty, and with finding the gradient of a graph. For several candidates, credit was not awarded because the points were not plotted correctly, the line of best fit or worst acceptable line was not drawn correctly or coordinates were wrongly read off.

To be successful, candidates should be advised that mathematical working in the latter parts of the question requires a clear statement of the equation used with correct substitution of numbers, and the answer calculated with a unit including the correct power of ten. Candidates should set out their working in a logical and readable manner.

Comments on specific questions

Question 1

Many of the candidates correctly identified the independent and dependent variables. Candidates should be encouraged then to consider the control of variables and to explicitly state the quantities that need to be kept constant to make the experiment a fair test. A significant number of candidates use the incorrect term 'control' rather than the correct term 'constant'.

Credit is available for the method of data collection. Candidates were awarded credit for a clearly labelled diagram. Diagrams should be drawn of the workable setup of the experiment. In this experiment, candidates needed to show clearly a method of fixing one end of the strip to a bench or horizontal surface by either a G-clamp or a heavy mass placed on top of the strip, and a labelled load/mass placed at the end of the unsupported part of the strip. Many diagrams showed the apparatus drawn in 'mid-air' which would not be a workable setup. There must be a reference level, e.g. floor or bench top shown. Further credit was awarded for the method of attaching the load to the strip e.g. glue/tape.

Most candidates gained credit for suggesting a metre rule to measure both *L* and *s* and a balance to measure *M*. Using a 'scale' to measure either distances or mass was not credited as it was too vague. Stronger candidates gained further credit by drawing a metre rule vertically attached to a stand to determine *s*. There was also credit available for the method of ensuring the rule was vertical; it was expected that the set square should be drawn on the diagram with a horizontal surface shown. Some candidates drew labelled metre rules on their diagrams with the distances *L* and *s* clearly indicated.

Credit was available for the analysis of data. Many candidates selected the correct axes for the graph but there was a significant number of candidates who incorrectly suggested plotting *s* against *L*. Candidates must explicitly state the quantities to be plotted on each axis either in the text or on drawn axes – credit is not given for just writing $y = mx + c$ under an expression. Having suggested an appropriate graph, candidates needed to explain how the graph would confirm the suggested relationship. Candidates need to use the words 'relationship is valid if' and the word 'straight' to describe the line, and 'passing through the origin'. Some candidates suggested the plotting of a logarithmic graph. In this case, to test the relationship they needed to state how the gradient of the graph would confirm the relationship to be valid. Candidates then needed to explain how the constant *E* would be determined; *E* needed to be the subject of the equation.

The additional detail section had a maximum of six marks that could be awarded. 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. It is essential that candidates' answers are relevant to the experiment in question rather than general 'textbook' rules for working in the laboratory.

Credit was available for a safety precaution. A clearly reasoned precaution relevant to the experiment was required, including a reason why the safety precaution is selected. Valid safety precautions were the use of a cushion or sand box in case the mass or load falls, or goggles in case the strip snaps or recoils.

Other creditworthy additional detail included recording an initial vertical height and then a new height and finding the difference as *s*, using a micrometer to measure *t* and waiting for the block to be stationary or in equilibrium before measuring *s*. Candidates could also gain credit by describing repeating the measurement of *s* for each value of *L* and for repeating readings of *b* and *t* at different points along or across the strip. Candidates should explain how the repeat measurements are made – just 'repeat measurements of *t*' did not gain credit. There was also credit available for candidates who discussed how to ensure that the strip was perpendicular to the bench. Stronger candidates indicated a labelled set square on the diagram or discussed measuring *L* from either side of the strip.

Question 2

(a) Candidates who were mathematically confident were able to work through the algebra and achieve credit. Weaker candidates should be encouraged to use the white space on the question paper to rearrange the equation into an equation of a straight line.

(b) Completing the table was very straightforward. However, many candidates did not consider the appropriate number of significant figures, or incorrectly rounded the third significant figure. Since values of I were recorded to two significant figures, values of $1/I$ should have been recorded to two or three significant figures. Most candidates calculated the uncertainties correctly.

(c) (i) The points and error bars were straightforward to plot. A significant number of candidates drew large blobs for the plotted points which could not be given credit; the diameter of each point should be less than half a small square. Candidates need to take care over the accuracy of the error bars and ensure that the error bar is symmetrical.

(ii) Candidates who are successful appear to be using a sharp pencil and a transparent 30 cm ruler which covers all of the points. Candidates should ensure that there is a balance of points about the line of best fit, and in particular should not simply draw the line through the highest and lowest points without considering the position of the other points.

The worst acceptable line was drawn well in general with a noticeable number of strong candidates drawing a line which passed through all error bars. Candidates should clearly indicate the lines drawn. Where a dashed line is used to represent the worst acceptable line, the dashed parts of the line should cross the error bars.

(iii) Most candidates clearly demonstrated the points that they used to calculate the gradient. Some candidates misread coordinates or did not use a sufficiently large triangle. A small number of candidates chose points that did not lie on the lines, often instead using data from the table that is close to the line. Candidates should be encouraged to select two points which are easy to read from the graph. They should be encouraged to read carefully the quantities from the axes and to pay attention to powers of ten and units. When determining the uncertainty in the gradient, candidates need to show their working including the coordinates that they have used from the worst acceptable line.

(d) Most candidates correctly determined the average e.m.f. of the battery. A very large number of candidates did not include the correct absolute uncertainty. Where readings are repeated, the absolute uncertainty is equal to half the range of the values. Stronger candidates showed their working e.g. $\frac{1}{2} \times (9.6 - 9.2) = 0.2$.

(e) (i) Candidates should clearly show how the gradient is used – credit is not given for substituting data vales from the table into the expression. Stronger candidates evaluated the expression and then showed the rounding to two or three significant figures. Credit was given for the correct power of ten and units for *K*. Candidates should be encouraged to consider both the powers of ten and the units used on the plotted graph. Some candidates confused the degree symbol '°' for the unit of angle with the variable and wrote it as 'θ'.

(ii) Stronger candidates clearly presented their working in a readable, logical order. Many of the candidates correctly added the percentage uncertainties in the gradient and *E*. A few candidates chose the maximum or minimum method of finding the uncertainty in *K* and then calculated the percentage uncertainty. For this method, candidates needed to choose carefully the values of *E* and gradient. Candidates attempting to find the percentage uncertainty by maximum/minimum methods must demonstrate clearly their method.

(f) Candidates needed to show clear and logical working for this part. Clear substitution of numbers into equations was needed both to determine θ and the absolute uncertainty in θ. The first mark was for a straightforward substitution into the given formula. Many candidates correctly converted the current from milliampere to ampere. Some stronger candidates determined θ using the gradient.

There were many methods to determine the absolute uncertainty in θ which were dependent on the method of determining θ. Many candidates chose to add percentage uncertainties and then determine the absolute uncertainty. Correct maximum or minimum methods were also allowed.

Some candidates added an uncertainty of ± 0.1 mA to I, having seen the current values in Fig. 2.3 presented with uncertainties of ± 0.1 mA. This was not required but correct answers using this uncertainty were given credit.

PHYSICS

Paper 9702/52
Planning, Analysis and Evaluation

Key messages

- Candidates should be encouraged to read all the questions carefully before answering them to understand what is required.
- Planning a few key points before answering **Question 1** is useful.
- In **Question 1**, candidates' responses should include detailed explanations of experimental procedures such as how to control variables, how to take measurements and how to analyse the data.
- Graphical work should be carefully attempted and checked. Care is also needed when reading information from the graph.
- The numerical answers towards the end of **Question 2** require candidates to show all their working particularly when determining uncertainties. A full understanding of significant figures and the treatment of uncertainties is required. In particular, candidates must be aware of the differences between absolute uncertainties and percentage uncertainties.
- The practical skills required for this paper should be developed and practised with a 'hands on' approach throughout the course.

General comments

In **Question 1**, it is advisable that candidates should think carefully about the experiment following the points given on the question paper and to imagine how they would perform the experiment in the laboratory. There were some unworkable setups shown in diagrams and often some important measurements were omitted. Many candidates were successful in the analysis section with clear identification of how the constants could be determined. Many candidates did not provide enough additional detail. It is essential for candidates to have experienced practical work in preparation for answering this paper.

In **Question 2**, candidates should be familiar with completing a results table for quantities and their uncertainty, and with finding the gradient of a graph. For several candidates, credit was not awarded because the points were not plotted correctly, the line of best fit or worst acceptable line was not drawn correctly or coordinates were wrongly read off.

To be successful, candidates should be advised that mathematical working in the latter parts of the question requires a clear statement of the equation used with correct substitution of numbers, and the answer calculated with a unit including the correct power of ten. Candidates should set out their working in a logical and readable manner.

Comments on specific questions

Question 1

Many of the candidates correctly identified the independent and dependent variables. Candidates should be encouraged then to consider the control of variables and to explicitly state the quantities that need to be kept constant to make the experiment a fair test. A significant number of candidates use the incorrect term 'control' rather than the correct term 'constant'.

Credit is available for the method of data collection. Candidates were awarded credit for a clearly labelled diagram. Diagrams should be drawn of the workable setup of the experiment. In this experiment, candidates needed to show clearly a labelled load/mass placed at point P. Further credit was awarded for the method of attaching the load to point P. It was expected that, if the load was suspended, the string or mass holder would be labelled.

Most candidates gained credit for stating that they would use a protractor to measure the angle θ and a balance to measure *m*. Using a 'scale' to measure either distances or mass was not credited as it was too vague. Stronger candidates indicated the use of a metre rule to measure *L*. Some candidates attempted to describe how to determine the angle by trigonometry, but this is unlikely to have given a more accurate value than using a protractor.

An important part of this experiment was that the angle needed to be changed slowly until the block just toppled. Many candidates did not include this in their method of data collection.

Credit was available for the analysis of data. Many candidates selected the correct axes for the graph but a significant number of candidates incorrectly suggested plotting θ against $1/m$. With the expression given, candidates would not have been able to plot a graph of *m* against $1/\cos\theta$. Candidates must explicitly state the quantities to be plotted on each axis either in the text or on drawn axes – credit is not given for just writing $y = mx + c$ under an expression. Having suggested an appropriate graph, candidates needed to explain how the graph would confirm the suggested relationship. Candidates need to use the words 'relationship is valid if' and the word 'straight' to describe the line. In this experiment, the line would not pass through the origin (for most of the commonly plotted graphs) and this was not credited. Candidates then needed to explain how the gradient and/or *y*-intercept could be used to determine the constant α, and α needed to be the subject of the equation. Additional detail credit was available for rearranging the given expression into an equation of a straight-line format. Some candidates suggested other graphs to plot such as $(2L\cos\theta - w)$ against $1/m$; appropriate reasoning and values for α consistent with the graph could gain credit.

The additional detail section had a maximum of six marks that could be awarded. 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. It is essential that candidates' answers are relevant to the experiment in question rather than general 'textbook' rules for working in the laboratory.

Credit was available for a safety precaution. A clearly reasoned precaution relevant to the experiment was required, including a reason why the safety precaution is selected. An example safety precaution was the use of a cushion or sand box in case the block or load falls.

Other creditworthy additional detail included measuring the length, width and height of the block to determine the volume *V* of the block and the equation for the volume of the block in terms of length, width and height. Candidates could also describe repeating the measurement of θ for each value of *m*. Candidates should explain exactly what they intend to repeat – a vague statement such as 'repeat measurements of θ' did not gain credit. Candidates should be encouraged to explain improvements to experimental techniques.

Question 2

(a) Candidates who were mathematically confident were able to work through the algebra and achieve credit. Weaker candidates should be encouraged to use the white space on the question paper to rearrange the equation into an equation of a straight line.

(b) Completing the table appeared to be challenging for candidates. Most candidates were able to calculate a mean value for *T* but often did not use an appropriate number of significant figures. Since values of *t* were recorded to three significant figures, values of *T* should have been recorded to three (or four) significant figures. Many candidates did not determine the absolute uncertainty in *T* correctly. When readings are repeated, the absolute uncertainty is equal to half the range of the values; the absolute uncertainty in *T* should have increased from 0.01 s to 0.02 s.

Candidates were then required to determine T^2. Many candidates incorrectly rounded the answers. For example, $0.57^2 = 0.3249$ which rounds to 0.325 (to three significant figures) or 0.32 (to two significant figures). The final part of the question was to determine the absolute uncertainty in T^2.

Many weaker candidates incorrectly just doubled the absolute uncertainty in *T*. Candidates need to understand the rules for combining uncertainties.

(c) (i) The points and error bars were straightforward to plot. A significant number of candidates drew large blobs for the plotted points which could not be given credit; the diameter of each point should be less than half a small square. Candidates need to take care over the accuracy of the error bars and ensure that the error bar is symmetrical.

(ii) Candidates who are successful appear to be using a sharp pencil and a transparent 30 cm ruler which covers all of the points. Candidates should ensure that there is a balance of points about the line of best fit, and in particular should not simply draw the line through the highest and lowest points without considering the position of the other points.

The worst acceptable line was drawn well in general with a noticeable number of strong candidates drawing a line which passed through all error bars. Candidates should clearly indicate the lines drawn. Where a dashed line is used to represent the worst acceptable line, the dashed parts of the line should cross the error bars.

(iii) Most candidates clearly demonstrated the points that they used to calculate the gradient. Some candidates misread coordinates or did not use a sufficiently large triangle. A small number of candidates chose points that did not lie on the lines, often instead using data from the table that is close to the line. Candidates should be encouraged to select two points which are easy to read from the graph. They should be encouraged to read carefully the quantities from the axes and to pay attention to powers of ten and units. When determining the uncertainty in the gradient, candidates need to show their working including the coordinates that they have used from the worst acceptable line.

(d) (i) Candidates should clearly show how the gradient is used – credit is not given for substituting data vales from the table into the expression. The calculated value of *M* needed to be given to two or three significant figures with a correct unit. The unit should have been kilogram, kg. Candidates should be encouraged to consider both the powers of ten and the units used on the plotted graph. Stronger candidates evaluated the expression and then showed the rounding to an appropriate number of significant figures.

(ii) Many candidates who fully understood the treatment of uncertainties realised that the percentage uncertainty in *M* was equal to the percentage uncertainty in the gradient. Stronger candidates clearly presented their working in a readable, logical order. A few candidates chose the maximum or minimum method of finding the uncertainty in *M* and then calculated the percentage uncertainty. Candidates attempting to find the percentage uncertainty by maximum/minimum methods must demonstrate clearly their method.

(e) Candidates needed to show clear and logical working for this part. Clear substitution of numbers into equations was needed both to determine *k* and the absolute uncertainty in *k*. The first mark was for a straightforward substitution into the given formula. Some stronger candidates determined *k* using the gradient.

There were many methods to determine the absolute uncertainty in *k* which were dependent on the method of determining *k*. Many candidates chose to add percentage uncertainties and then determine the absolute uncertainty. A common error was to state that the absolute uncertainty in T^2 was 0.02. When the $T = 2.50 \pm 0.01$, $T^2 = 6.25 \pm 0.05$, i.e. the absolute uncertainty is 0.05. Correct maximum or minimum methods were also allowed.

PHYSICS

Paper 9702/53
Planning, Analysis and Evaluation

Key messages

- Candidates should be encouraged to read all the questions carefully before answering them to understand what is required.
- Planning a few key points before answering **Question 1** is useful.
- In **Question 1**, candidates' responses should include detailed explanations of experimental procedures such as how to control variables, how to take measurements and how to analyse the data.
- Graphical work should be carefully attempted and checked. Care is also needed when reading information from the graph.
- The numerical answers towards the end of **Question 2** require candidates to show all their working particularly when determining uncertainties. A full understanding of significant figures and the treatment of uncertainties is required. In particular, candidates must be aware of the differences between absolute uncertainties and percentage uncertainties.
- The practical skills required for this paper should be developed and practised with a 'hands on' approach throughout the course.

General comments

In **Question 1**, it is advisable that candidates should think carefully about the experiment following the points given on the question paper and to imagine how they would perform the experiment in the laboratory. There were some unworkable setups shown in diagrams and often some important measurements were omitted. Many candidates were successful in the analysis section with clear identification of how the constants could be determined. Many candidates did not provide enough additional detail. It is essential for candidates to have experienced practical work in preparation for answering this paper.

In **Question 2**, candidates should be familiar with completing a results table for quantities and their uncertainty, and with finding the gradient of a graph. For several candidates, credit was not awarded because the points were not plotted correctly, the line of best fit or worst acceptable line was not drawn correctly or coordinates were wrongly read off.

To be successful, candidates should be advised that mathematical working in the latter parts of the question requires a clear statement of the equation used with correct substitution of numbers, and the answer calculated with a unit including the correct power of ten. Candidates should set out their working in a logical and readable manner.

Comments on specific questions

Question 1

Many of the candidates correctly identified the independent and dependent variables. Candidates should be encouraged then to consider the control of variables and to explicitly state the quantities that need to be kept constant to make the experiment a fair test. A significant number of candidates use the incorrect term 'control' rather than the correct term 'constant'.

Credit is available for the method of data collection. Candidates were awarded credit for a clearly labelled diagram. Diagrams should be drawn of the workable setup of the experiment. In this experiment, candidates needed to show clearly a method of fixing one end of the strip to a bench or horizontal surface by either a G-clamp or a heavy mass placed on top of the strip, and a labelled load/mass placed at the end of the unsupported part of the strip. Many diagrams showed the apparatus drawn in 'mid-air' which would not be a workable setup. There must be a reference level, e.g. floor or bench top shown. Further credit was awarded for the method of attaching the load to the strip e.g. glue/tape.

Most candidates gained credit for suggesting a metre rule to measure both *L* and *s* and a balance to measure *M*. Using a 'scale' to measure either distances or mass was not credited as it was too vague. Stronger candidates gained further credit by drawing a metre rule vertically attached to a stand to determine *s*. There was also credit available for the method of ensuring the rule was vertical; it was expected that the set square should be drawn on the diagram with a horizontal surface shown. Some candidates drew labelled metre rules on their diagrams with the distances *L* and *s* clearly indicated.

Credit was available for the analysis of data. Many candidates selected the correct axes for the graph but there was a significant number of candidates who incorrectly suggested plotting *s* against *L*. Candidates must explicitly state the quantities to be plotted on each axis either in the text or on drawn axes – credit is not given for just writing $y = mx + c$ under an expression. Having suggested an appropriate graph, candidates needed to explain how the graph would confirm the suggested relationship. Candidates need to use the words 'relationship is valid if' and the word 'straight' to describe the line, and 'passing through the origin'. Some candidates suggested the plotting of a logarithmic graph. In this case, to test the relationship they needed to state how the gradient of the graph would confirm the relationship to be valid. Candidates then needed to explain how the constant *E* would be determined; *E* needed to be the subject of the equation.

The additional detail section had a maximum of six marks that could be awarded. 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. It is essential that candidates' answers are relevant to the experiment in question rather than general 'textbook' rules for working in the laboratory.

Credit was available for a safety precaution. A clearly reasoned precaution relevant to the experiment was required, including a reason why the safety precaution is selected. Valid safety precautions were the use of a cushion or sand box in case the mass or load falls, or goggles in case the strip snaps or recoils.

Other creditworthy additional detail included recording an initial vertical height and then a new height and finding the difference as *s*, using a micrometer to measure *t* and waiting for the block to be stationary or in equilibrium before measuring *s*. Candidates could also gain credit by describing repeating the measurement of *s* for each value of *L* and for repeating readings of *b* and *t* at different points along or across the strip. Candidates should explain how the repeat measurements are made – just 'repeat measurements of *t*' did not gain credit. There was also credit available for candidates who discussed how to ensure that the strip was perpendicular to the bench. Stronger candidates indicated a labelled set square on the diagram or discussed measuring *L* from either side of the strip.

Question 2

(a) Candidates who were mathematically confident were able to work through the algebra and achieve credit. Weaker candidates should be encouraged to use the white space on the question paper to rearrange the equation into an equation of a straight line.

(b) Completing the table was very straightforward. However, many candidates did not consider the appropriate number of significant figures, or incorrectly rounded the third significant figure. Since values of I were recorded to two significant figures, values of $1/I$ should have been recorded to two or three significant figures. Most candidates calculated the uncertainties correctly.

(c) (i) The points and error bars were straightforward to plot. A significant number of candidates drew large blobs for the plotted points which could not be given credit; the diameter of each point should be less than half a small square. Candidates need to take care over the accuracy of the error bars and ensure that the error bar is symmetrical.

(ii) Candidates who are successful appear to be using a sharp pencil and a transparent 30 cm ruler which covers all of the points. Candidates should ensure that there is a balance of points about the line of best fit, and in particular should not simply draw the line through the highest and lowest points without considering the position of the other points.

The worst acceptable line was drawn well in general with a noticeable number of strong candidates drawing a line which passed through all error bars. Candidates should clearly indicate the lines drawn. Where a dashed line is used to represent the worst acceptable line, the dashed parts of the line should cross the error bars.

(iii) Most candidates clearly demonstrated the points that they used to calculate the gradient. Some candidates misread coordinates or did not use a sufficiently large triangle. A small number of candidates chose points that did not lie on the lines, often instead using data from the table that is close to the line. Candidates should be encouraged to select two points which are easy to read from the graph. They should be encouraged to read carefully the quantities from the axes and to pay attention to powers of ten and units. When determining the uncertainty in the gradient, candidates need to show their working including the coordinates that they have used from the worst acceptable line.

(d) Most candidates correctly determined the average e.m.f. of the battery. A very large number of candidates did not include the correct absolute uncertainty. Where readings are repeated, the absolute uncertainty is equal to half the range of the values. Stronger candidates showed their working e.g. ½ × (9.6 – 9.2) = 0.2.

(e) (i) Candidates should clearly show how the gradient is used – credit is not given for substituting data vales from the table into the expression. Stronger candidates evaluated the expression and then showed the rounding to two or three significant figures. Credit was given for the correct power of ten and units for *K*. Candidates should be encouraged to consider both the powers of ten and the units used on the plotted graph. Some candidates confused the degree symbol '°' for the unit of angle with the variable and wrote it as 'θ'.

(ii) Stronger candidates clearly presented their working in a readable, logical order. Many of the candidates correctly added the percentage uncertainties in the gradient and *E*. A few candidates chose the maximum or minimum method of finding the uncertainty in *K* and then calculated the percentage uncertainty. For this method, candidates needed to choose carefully the values of *E* and gradient. Candidates attempting to find the percentage uncertainty by maximum/minimum methods must demonstrate clearly their method.

(f) Candidates needed to show clear and logical working for this part. Clear substitution of numbers into equations was needed both to determine θ and the absolute uncertainty in θ. The first mark was for a straightforward substitution into the given formula. Many candidates correctly converted the current from milliampere to ampere. Some stronger candidates determined θ using the gradient.

There were many methods to determine the absolute uncertainty in θ which were dependent on the method of determining θ. Many candidates chose to add percentage uncertainties and then determine the absolute uncertainty. Correct maximum or minimum methods were also allowed.

Some candidates added an uncertainty of ± 0.1 mA to I, having seen the current values in Fig. 2.3 presented with uncertainties of ± 0.1 mA. This was not required but correct answers using this uncertainty were given credit.