PHYSICS

Paper 9702/11
Multiple Choice

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

General comments

Candidates should always read each question through in its entirety before looking at the answer options, taking particular care when, for instance, a question asks 'Which statement is **not** correct?'. All four answer options should be considered carefully, trying to justify eliminating three of the options as a check to make sure the answer selected is the correct one.

When answering numerical questions, it is a good idea to try to calculate the answer before looking at the answer options. Candidates also need to ensure that the units used in a calculation are **consistent**, particularly if the information includes prefixes such as k, μ or M, or data which includes areas in mm^2 or cm^2 or volumes in mm^3 or cm^3.

Only a small number of candidates (8) sat this particular examination. They found **Questions 8**, **14**, **15**, **18**, **20**, **28**, **30**, **34** and **36** particularly difficult, but found **Questions 17**, **19**, **23** and **27** relatively straightforward.

Comments on specific questions

Question 8

Half the candidates selected answer **B** (a graph of kinetic energy against time) rather than the correct answer **C**. An object falling in air for a long time will initially accelerate but eventually reach a constant (terminal) velocity. A graph of kinetic energy $\left(\frac{1}{2}mv^2\right)$ against time will initially have a positive gradient but eventually become horizontal when the velocity, and hence the kinetic energy, becomes constant.

The gravitational potential energy (taking ground level as the 'zero' of gravitational potential energy) is *mgh*, where *h* is the height above the ground. A graph of gravitational potential energy against *h* will be a straight line through the origin (answer **C**).

Question 14

Only 1 of the 8 candidates answered this question correctly. The easiest way of tacking this problem is to consider the equilibrium of the U-shaped column of liquid.

The pressure from the gas tap on one side must equal the combined pressure of the atmosphere and the pressure exerted by the extra height of liquid on the other side.

$p_{\text{gas tap}} = p_{\text{atmosphere}} + \text{'}\rho gh\text{'}$
$= 101 \times 10^3 + 1000 \times 9.81 \times (31.4 - 10.2) \times 10^{-2}$
$= 103 \times 10^3$ Pa (answer **D**)

This question is an example of where candidates need to exercise care in dealing with prefixes and units. For the calculation to be correct, the kilopascals (kPa) must be converted into pascals and the height difference in cm must be converted into metres.

Question 15

Only 2 of the 8 candidates answered this correctly. Applying the principle of conservation of energy:

$(PE)_P + (KE)_P = (PE)_Q + (KE)_Q$ + work done moving from P to Q
$(KE)_Q = [(PE)_P - (PE)_Q] + (KE)_P$ – work done moving from P to Q
$= 50 + 5 - 10$
$= 45$ kJ (answer **B**)

Question 18

Only 2 of the 8 candidates answered this correctly, with the others selecting answer **C** or **D** rather than the correct answer **B**. If the output force of the train's engine is *F*, then (using *F* = *ma*):

$F - 15\times10^3 = 300\,000 \times 0.80$
$F = 2.55 \times 10^5$ N

The output power of the train's engine is '*Fv*' = $2.55 \times 10^5 \times 5.0 = 1.3 \times 10^6$ W (answer **C**).
Some of this output power is used against the resistive force; the rest accelerates the train, increasing its kinetic energy.

[rate of increase of KE] = [output power of train's engine] – [work done per second against resistive force]

$= 1.3 \times 10^6 - (15 \times 10^3 \times 5.0)$
$= 1.2 \times 10^6$ W (answer **B**)
(An alternative method: $\frac{d}{dt}\left(\frac{1}{2}mv^2\right) = mv\frac{dv}{dt} = mva = 300\,000 \times 5.0 \times 0.80 = 1.2 \times 10^6$ W)

Question 20

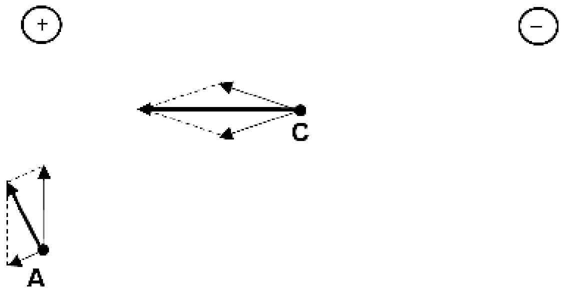
No candidate answered this question correctly. The area under graph P is the work done in stretching the rubber cord (option **D**); the area under graph Q is the energy that can be recovered as 'mechanical' energy (option **A**). The difference between the two (the shaded area) is energy which is 'lost' as internal energy (heat) in the rubber. (Known as elastic hysteresis, it is the reason car tyres get hot as they are compressed and released each revolution). The correct answer is **C**.

Question 28

Only two candidates answered this question correctly. The sound waves from the two loudspeakers **do not** have to be emitted in phase for complete destructive interference to occur. They could, for example, be emitted 180° out of phase – if they had equal amplitudes they would then cancel out completely at the point on the path of the microphone that is equidistant from the two loudspeakers. The two sound waves do need to have similar amplitudes for the sound to cancel out completely at some point along the path of the microphone. If one loudspeaker was much louder than the other, the loudness of the sound detected along the path of the microphone would fluctuate but would not cancel out completely.

Question 30

The majority of the candidates selected answer **C** rather than the correct answer **A**. At all four points an electron would experience an attractive force towards the positively charged sphere and a repulsive force exerted by the negatively charged sphere. The resultant of these two forces for the electrons at **A** and **C** are shown below.



Question 34

No candidate answered this question correctly. It is important to note that the cable is, in effect, a wire of length 2*L*. The current in the wire is 2.50 A and the potential difference across it is 1.5 V. The resistance of this wire is:

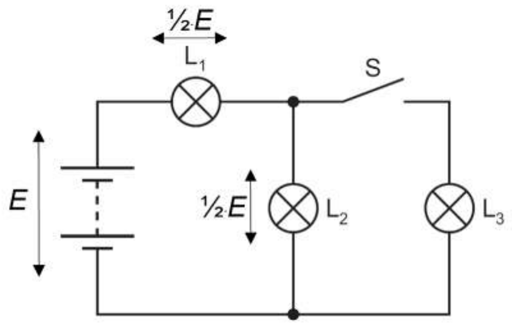
$$R = \frac{V}{I} = \frac{1.5}{2.50} = 0.60$$

Using $R = \frac{\rho L}{A}$: $2L = \frac{RA}{\rho} = \frac{0.60 \times 6.00 \times 10^{-7}}{1.70 \times 10^{-8}} = 21.2\ \text{m}$ (answer **B**)

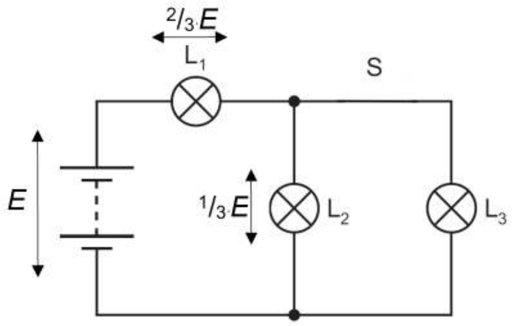
L = 10.6 m (the correct answer, **A**)

Question 36

No candidate answered this question correctly. Let the e.m.f. of the battery be E and assume the resistance of each lamp is constant. With the switch S open, the potential difference across L_1 and L_2 is the same, and equal to $\frac{1}{2}E$ as the battery has negligible internal resistance.



With the switch S closed, the parallel combination of lamps L_2 and L_3 now have a combined resistance of half the resistance of one of the lamps. The p.d. across lamp L_1 is now twice as much as the p.d. across L_2 and L_3. It has increased from $\frac{1}{2}E$ to $2/3\,E$, so lamp L_1 will be brighter. The p.d. across lamp L_2 has decreased from $\frac{1}{2}E$ to $\frac{1}{3}E$ so lamp L_2 will be dimmer.



PHYSICS

Paper 9702/12
Multiple Choice

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

General comments

Candidates should always read each question through in its entirety before looking at the four possible answers, taking particular care when, for instance, a question asks which statement is **not** correct. All four answer options should be considered carefully, trying to justify eliminating three of the options as a check to make sure the answer selected is the correct one.

When answering numerical questions, it is a good idea to try to calculate the answer before looking at the answer options. Candidates need to ensure that the units used in any calculation are consistent, particularly if the information includes prefixes such as k, μ or M, or data which includes areas in mm^2 or cm^2 or volumes in mm^3 or cm^3.

Candidates found **Questions 21**, **22**, **30**, **33**, **34**, **37** and **38** difficult. They found **Questions 9**, **12**, **19**, **25** and **28** relatively straightforward.

Comments on specific questions

Question 6

The majority of the candidates answered this question correctly, though many thought that the displacement at time $t = 3.0$ s would be 15 m below X rather than 15 m above X. As the stone is thrown vertically upwards with an initial velocity of 20 m s^{-1}, and this is shown as positive on the velocity–time graph, the area of the graph above the x-axis represents an upwards (positive) displacement and the area below the x-axis represents a downward (negative) displacement. The net displacement at time $t = 3.0$ s must be positive because the area above the x-axis (for $t = 0$ to $t = 2.0$ s) is greater than the area below the x-axis (for $t = 2.0$ s to $t = 3.0$ s).

Question 7

Less than half of the candidates answered this question correctly, with many selecting **C** or **D** rather than the correct answer **A**. Applying $F = ma$ down the slope, the acceleration a of the mass down the slope is given by the equation $5.0\,g \sin 30° = 5.0\,a$ which then gives $a = 4.91$ m s^{-2}. The distance moved is then obtained using $s = ½at^2$.

Question 11

Many candidates selected **A** rather than the correct answer **C**.

For the first collision, in order to conserve linear momentum, $Mv = mu$ and so $v = (m/M)u$.

For the second collision, the equivalent expression is $2Mv_2 = 2m \times 2u$. Comparison of this equation with the equation for the first collision shows that $v_2 = 2v$, which is answer **C**.

Question 14

Common mistakes were either to use cos 20° rather than sin 20° when resolving forces vertically, or to equate the weight of the man to $T \sin 20°$ rather than $2T \sin 20°$.

Question 16

Many candidates found this question difficult, and many candidates selected **D** rather than the correct answer **A**. As air resistance is negligible, the combined kinetic energy and gravitational potential energy of the ball remains constant. For **D** to be true, the potential energy of the ball must increase at a constant rate (i.e. increase by equal amounts in equal times). This is true for an object moving upwards at constant speed but not when the speed is changing.

Question 21

The wire is already extended by 3.0 mm. The extra work needed to extend the wire by a further 2.0 mm is the total area under the force–extension graph between extensions of 3.0 mm and 5.0 mm. This area is given by $½(100 + 60) \times 2.0 \times 10^{-3} = 0.16$ J.

Candidates selecting **A** may have misinterpreted the question, calculating the work done to extend a previously unstretched wire by 2.0 mm (the area under the graph between 0 and 2.0 mm).

Question 22

Many candidates selected **C** rather than the correct answer **D**. Candidates needed to recall the equation $v = f\lambda$ and combine it with the equation given to obtain $f^2\lambda = g/2\pi$. A graph of f^2 against $1/\lambda$ would then give a straight line through the origin with gradient $g/2\pi$. Candidates selecting **C** may have correctly recalled $v = f\lambda$ but not considered that the waves do not all have the same speed.

Question 23

Candidates found this question difficult. Although the context is waves, this question tests whether candidates understand that the gradient of a displacement–time graph of an object is the velocity of the object.

Whenever the gradient of the displacement–time graph is zero, the velocity, and hence the kinetic energy, of the air particle is zero. The gradient is zero at time $t = 0$, but **A** and **C** have non-zero values at time $t = 0$, so both these answers can be rejected.

The velocity is a maximum positive or negative value when the displacement is zero. The kinetic energy at these points is always a (maximum) positive value as kinetic energy is proportional to the square of the velocity. The correct answer is therefore **D** rather than **B**.

Question 24

The first loud sound corresponds to the first-order stationary sound wave in the cylinder, with a displacement node at the surface of the water and a displacement antinode at the open end of the cylinder. The second loud sound corresponds to the second-order stationary sound wave, again with a node at the surface of the water and an antinode at the open end of the cylinder, with one other node between the two. The change in the water level is the distance between two nodes, $\lambda/2$. From this the wavelength and frequency of the sound can be calculated.

Question 30

Many candidates selected the incorrect answer **D**. Increasing the number of lines per metre in the diffraction grating implies that the slit separation d is made smaller. From the diffraction grating equation $n\lambda = d \sin \theta$, it follows that the maxima will then occur at larger angles, so fewer of them in total will appear on the screen.

Increasing the distance between the grating and the screen will also reduce the number of maxima observed on the screen as the bright spots spread further apart. Increasing the intensity of the incident light will just make the bright spots brighter.

Increasing the frequency of the incident light implies a smaller wavelength of light. The diffraction grating equation then shows that the different order maxima will occur at smaller angles. More of them will then be observed on the screen.

Question 33

The incorrect answers **B**, **C** and **D** were all commonly chosen. The current at a point on the edge of the disc is the total charge passing per unit time. As the disc rotates n revolutions in unit time, a total charge of $4Q$ passes n times in unit time. The current is therefore $4Q \times n$ (answer **A**).

Question 34

More candidates selected the incorrect answer **C** to this question than the correct answer **B**. Using $P = I^2R$, the resistance R of the fixed resistor X is $R = 7.2/3.0^2 = 0.80\,\Omega$. If the power increases by 50%, then the new current is given by $I^2 = P/R = 7.2 \times 1.5/0.80$. Taking the square root gives $I = 3.7\,\text{A}$.

Question 35

From the first graph, when the p.d. across the resistor is 3.3 V, the current in the resistor is 0.3 A. As the resistor and the filament lamp are in series, this must also be the current in the filament lamp. From the second graph, when the current in the filament lamp is 0.3 A, the p.d. across the lamp is 4.2 V. The resistance R of the lamp is then $R = V/I = 4.2/0.3 = 14\,\Omega$.

Question 37

In the circuit given, the reading on the voltmeter is zero, so the potentials at the two junctions either side of the voltmeter must be the same. This means that $R_T/3.00 = 4.80/2.00$ where R_T is the combined resistance of the two parallel resistors in the upper-right branch (R and $14.4\,\Omega$). Solving this gives $R_T = 7.2\,\Omega$, and therefore the unknown resistor R must be another $14.4\,\Omega$ resistor.

Question 38

Candidates found this question difficult. One method is to apply Kirchhoff's second law to closed loops around the circuit. When the sliding contact is at end P, the voltmeter will show 3 V because it is in a closed loop containing only the 3 V cell. When the contact is moved to end Q, a loop can be drawn containing both cells and the voltmeter, so the voltmeter will now show 6 V.

PHYSICS

Paper 9702/13
Multiple Choice

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

General comments

Candidates should always read each question through in its entirety before looking at the four possible answers, taking particular care when, for instance, a question asks which statement is **not** correct. All four answer options should be considered carefully, trying to justify eliminating three of the options as a check to make sure the answer selected is the correct one.

When answering numerical questions, it is a good idea to try to calculate the answer before looking at the answer options. Candidates need to ensure that the units used in any calculation are consistent, particularly if the information includes prefixes such as k, μ or M, or data which includes areas in mm^2 or cm^2 or volumes in mm^3 or cm^3.

Candidates found **Questions 8**, **11**, **16** and **26** difficult. They found **Questions 2**, **3**, **17**, **23**, **24** and **28** relatively straightforward.

Comments on specific questions

Question 1

The majority of the candidates answered this question correctly, though some chose **A** or **C**. A quick way to answer this question would be to calculate the cube root of each volume, to find approximate values for the 'diameter' of the football. This shows that **A** is too small and **C** is too large.

Question 6

The majority of the candidates answered this question correctly, though some candidates must have added the area of the graph below the *x*-axis rather than subtracting it.

Question 8

Candidates found this question difficult, with many selecting **A** or **C** rather than the correct answer **B**. Care needs to be taken to ensure consistent units are used in calculations and especially, in this question, when converting mm^2 to m^2. The values needed are:

volume of paint ejected in one second = $400 \times 2.5 \times (0.4 \times 10^{-6}) = 4.0 \times 10^{-4}\,m^3$
mass of paint ejected in one second = $900 \times 4.0 \times 10^{-4} = 0.36\,kg$
change of momentum per unit time = $0.36 \times 2.5 = 0.90\,N$.

Question 11

Less than half of the candidates selected the correct answer **A**. As the air bubble is moving upwards, the viscous drag force *V* must be acting downwards, which eliminates option **D**.

The lengths of the arrows indicate the relative sizes of the three forces. Options **C** and **D** both have weights that are large (similar to or larger than the upthrust) which could not be true for an air bubble in a liquid.

As the air bubble is rising at a constant speed, the resultant force on the bubble must be zero. In **B**, $(W + V)$ is less than *U* so this bubble cannot have zero resultant force. The arrows add up to give a resultant force of zero for **A**.

Question 15

The majority of the candidates answered this question correctly, though a significant number of candidates selected **B** or **C** rather than the correct answer **D**. The density of the solid cylinder does not affect the upthrust force on the cylinder, eliminating **A** and **B** which both contain ρ_C. Answer **C** can also be rejected as the depth *H* does not affect the upthrust.

Question 16

Fewer than half of the candidates answered this question correctly, with many selecting **C** rather than the correct answer **B**. As the ball bounces elastically, no kinetic energy is lost as heat and sound. When the ball hits the horizontal surface it decelerates, losing kinetic energy but gaining elastic potential energy as the ball is compressed. At some instant, the ball will momentarily have zero velocity and zero kinetic energy before springing back up, gaining kinetic energy as it does so.

Question 18

Most candidates answered this question correctly, though a common incorrect answer was **B**. The object is released with an initial kinetic energy which is gradually converted into gravitational potential energy as the object rises. When it reaches its maximum height, the object is momentarily at rest so has no kinetic energy. At this point, using the principle of conservation of energy:

work done against air resistance = KE lost – GPE gained = $\frac{1}{2} \times 0.30 \times 8.0^2 - 0.30 \times 9.81 \times 1.9 = 4.0\,J$

Answer **B** is the increase in gravitational potential energy, and **C** is the kinetic energy lost.

Question 20

The majority of the candidates calculated the extension of the wires correctly. Some candidates calculated the extension for a platform supported by one wire rather than four.

Question 21

The majority of the candidates answered this question correctly. The most common incorrect answer was **D**, which comes from using *F*x rather than ½*Fx* for the work done.

Question 26

Candidates found this question difficult, and fewer than half of the candidates selected the correct answer **D**. The question simply tests the knowledge that microwaves and visible light waves (both being electromagnetic waves) travel at the same speed in a vacuum, so will cover the same distance in the same time. Candidates selecting **A** may have compared typical values for the wavelengths of microwaves and visible light to obtain the factor of 10^{-5}.

Question 27

The period of oscillation of the wave is 4.0 ms. In a time of 5.0 ms, the stationary wave will have completed 1.25 oscillations, so the displacement of point P will be zero.

Question 29

Just over half the candidates answered this question correctly, though many candidates selected **B** or **C**. Reducing the distance between the light source and the slits would have no effect on the spacing of the bright lines. Reducing the distance between the slits would increase the angular spacing of the maxima, so the bright lines on the screen would appear further apart.

Reducing the wavelength of the light by changing the source of light from red to blue (answer **A**) would decrease the angular separation of the maxima, so the bright lines on the screen would be closer together.

Question 32

Most candidates realised that, as some of the oil evaporates, the weight of the oil droplet (the downward force) decreases, causing the droplet to accelerate upwards. To stop the droplet, the electrostatic force also needs to be reduced, so the electric field strength must be reduced, and this is done by increasing the distance between the two metal plates, i.e. answer **D**.

Question 35

The majority of the candidates answered this question correctly, though several candidates selected **D** rather than the correct answer **C**. The 'length' of the metal cuboid increases by a factor of 5 which, on its own, would increase the resistance from 4.0 Ω to 20 Ω. The 'cross-sectional area' of the cuboid increases by a factor of 2 which reduces this resistance by half, from 20 Ω to 10 Ω.

Question 38

Although the majority of the candidates answered this question correctly, others found it difficult. As the galvanometer reads zero, V_{PS} must equal the e.m.f. of the solar cell (5.00 mV). It follows that:

$V_{PQ} = (100.0/40.0) \times V_{PS} = 1.25 \times 10^{-2}\,\text{V}$.

The current I in the potentiometer wire is $I = V_{PQ} / 5.00 = 2.5 \times 10^{-3}\,\text{A}$.

The potential difference across the resistor of resistance R is $2.000 - 1.25 \times 10^{-2} = 1.988\,\text{V}$

The resistance of the resistor is therefore $R = V/I = 1.988/(2.5 \times 10^{-3}) = 795\,\Omega$.

PHYSICS

Paper 9702/21
AS Level Structured Questions

Key messages

- It is essential that candidates learn the standard symbol formulae given in the syllabus. Recall of these formulae is needed in order to access many of the marks in the examination.
- In answering 'show that' questions, candidates should show all the steps in their calculation as well as giving the final answer. Successful candidates present clear calculations that contain all the required steps.
- Power-of-ten errors are a relatively common cause of lost credit. Often these occur due to the incorrect transcription of data from the question or from mistakes in dealing with unit prefixes. Candidates should be encouraged to take a moment to consider whether their final answers are of a reasonable order of magnitude as this check can often detect power-of-ten errors.

General comments

The marks varied over a wide range. Some of the weaker candidates did not attempt to give a response to a significant number of the question parts. Candidates should always be encouraged to attempt all questions, as marks can often be obtained for giving the appropriate starting formula.

In general, candidates would benefit from improving their knowledge of the definitions in the syllabus, as they found **Questions 1(a)(i)**, **3(a)**, **4(a)(i) and 7(a)** to be challenging.

Comments on specific questions

Question 1

(a) (i) The candidates were expected to refer to the product of the force and the perpendicular distance from the line of action of the force to the point.

(ii) Some candidates incorrectly gave 'N m' as the SI base units of the moment of a force.

(b) Most candidates found the calculation of the cross-sectional area to be straightforward, although some found the conversion of the unit from m^2 to mm^2 to be problematic.

(c) (i) The majority of the calculations were shown correctly.

(ii) Most candidates were able to calculate at least one moment about end A of the rod. However, some candidates found it difficult to apply the principle of moments to the question.

Question 2

(a) The constant gradient of the graph line was usually identified as the key feature. Some candidates referred to the gradient, but did not say that it was constant.

(b) Candidates usually attempted to apply the equations of uniformly accelerated motion. Some candidates incorrectly thought that the displacement over the first 0.20 s or the displacement over the last 0.70 s represented the height of the block when the string breaks.

(c) The gravitational potential energy formula was usually stated correctly. Candidates often carried forward an error in the height that they calculated in **(b)**.

(d) A minority of candidates realised that the gradient of their sketched line would be equal to the speed of the block and so drew a curved line from the origin with a gradient that decreased to zero. The most common incorrect answer was a straight line from the origin.

(e) Most answers correctly stated that there would be no effect on the speed with which the block hits the ground, but the required supporting explanation was often incorrect or omitted.

Question 3

(a) The most common incorrect response was to define acceleration as the product of mass and acceleration.

(b) (i) The kinetic energy formula was usually stated correctly, although arithmetic errors were sometimes made when calculating the value of the 'lost' kinetic energy.

(ii) Candidates needed to recognise that the final velocity of the ball has the opposite sign to the initial velocity of the ball. These opposite signs had to be considered when determining the change in momentum of the ball.

(iii) A significant number of candidates did not show the appropriate calculation.

(iv)1. Only a small minority of the candidates understood that the average force of the floor on the ball during the collision could be calculated by adding the ball's weight to the resultant force on the ball.

2. Many candidates were able to apply their knowledge of Newton's third law of motion to this part of the question. Often the mark was scored with an error carried forward from **(iv)1**.

Question 4

(a) (i) Successful candidates explicitly referred to 'cross-sectional area', rather than just 'area', when defining the stress of a wire.

(ii) A common error was to refer only to 'length' instead of 'original length', when defining the strain of a wire.

(b) (i) Stronger candidates were able to correctly combine the standard symbol expression for the Young modulus with a symbol expression for the gradient. Responses that methodically showed each step of the algebraic manipulation tended to be more successful than those that did not.

(ii) Candidates usually realised that the 'new' line would also be a straight line from the origin. However, most lines were incorrectly drawn below the original printed line instead of above it.

(iii)1. Candidates tended to either shade the correct the area or else not give a response at all.

2. A common misconception was that a wire must have exceeded its elastic limit when the force-extension graph is no longer a straight line.

(iv) Most candidates were able to explain that low precision means the values of the Young modulus have a large range.

Question 5

(a) The vast majority of answers were correct.

(b) Candidates who could recall the relationship between the intensity and amplitude of a wave were usually able to apply this relationship to the question.

Question 6

(a) Some candidates correctly described the requirement for the waves to move in opposite directions and overlap. However, it was seldom mentioned that the waves also need to have the same frequency or wavelength (and speed). Other candidates incorrectly stated that the waves needed to be in phase.

(b) (i) Candidates needed to give precise statements. A node occurs where the stationary wave has zero amplitude. It is insufficient to refer to ‘zero displacement’ instead of ‘zero amplitude’. The most common error was to give a statement that corresponded to an antinode rather than a node.

(ii) Stronger candidates appreciated that the distance between a node and an adjacent antinode is equal to a quarter of a wavelength and so they were then able to determine the correct value of the wavelength. A common error was to think that the distance between a node and an adjacent antinode is equal to half a wavelength.

(iii) The phase difference was usually stated correctly.

Question 7

(a) It is important that candidates are able to precisely recall the relevant definitions listed in the syllabus. Many answers to this part of the question contained definitions of the ohm that were only partially correct. Some candidates did not appreciate that a unit is defined in terms of other units.

(b) Successful candidates were able to recall and apply the appropriate symbol equation. Some candidates were not able to convert the unit nΩ m to Ω m as part of their calculation.

(c) (i) Only a small minority of the candidates could correctly explain 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.

(ii) The majority of the candidates were able to use Kirchhoff’s second law to give the correct expression.

(iii) Although stronger candidates found this part of the question to be straightforward, a significant number of weaker candidates did not attempt a response. Candidates should be encouraged to always attempt an answer, as marks can often be scored for the recall of a simple formula. In this case, it was possible to score a mark for stating a formula for electrical power.

Question 8

(a) Many candidates would benefit by increasing their knowledge of quarks. The most common correct similarity stated by the candidates was that the quarks have equal magnitudes of charge. The most common correct difference stated by the candidates was that the quarks have opposite signs of charge.

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

(ii) This was a ‘show that’ question and so candidates needed to carefully show their calculation. Sometimes a power-of-ten error was made.

(c) The majority of the candidates realised that work done is equal to the product of force and displacement. However, a common error was to use the total displacement of the nucleus rather than the component of the displacement that is parallel to the direction of the force. Candidates also needed to ensure that they did not make power-of-ten errors when substituting the value of the electric field strength and the value of the displacement.

PHYSICS

Paper 9702/22
AS Level Structured Questions

Key messages

- When answering 'show that' questions, candidates should show all the steps in their calculation as well as giving the final answer. Care should be taken to ensure that any minor steps are not omitted.
- Candidates should use the number of significant figures in the question data as a guide to the number of significant figures required in the final answer. In the majority of cases a minimum of two significant figures is appropriate for the final answer.
- Candidates should pay particular attention to the prefixes of units. If these are ignored or interpreted incorrectly, it can lead to a power-of-ten error in the final answer.
- Candidates should understand the command words that are used in each question. For example, 'state and explain' indicates that an explanation is required as part of the answer in order to obtain full credit. The syllabus contains a glossary of command words.

General comments

The marks awarded to candidates on this paper varied over the full mark range. Well-prepared candidates had no difficulty completing the paper in the allotted time.

There were certain question parts that most candidates found particularly challenging. Many candidates could have improved their answers to **Question 5(d)** by having a greater understanding of two-source interference using microwaves. The answers to **Question 7(b)** indicated that many candidates had difficulty interpreting a pattern of electric field lines.

Comments on specific questions

Question 1

(a) The majority of the candidates were able to complete the table correctly.

(b) (i) A significant number of the candidates described the speed of the train as increasing instead of decreasing, possibly because they had confused the distance–time graph with a speed–time graph. Others wrongly stated that the initial speed was zero. A small proportion of the candidates described the motion over the full 3.0 s which was unnecessary as the question only required a description of the motion over the first 1.0 s.

(ii) Many candidates determined the average speed from time t = 0 to time t = 2.0 s instead of using the gradient of the line to determine the instantaneous speed at time t = 2.0 s.

(c) Those candidates who realised that the average velocity of the train over one complete lap was zero could usually explain that this was due to the displacement being zero. Some candidates gave a general equation for calculating average velocity, but did not apply it to the question. A small minority of candidates correctly stated that the average velocity was zero, but did not give the required supporting explanation.

Question 2

(a) (i) Most candidates knew how to calculate the height of the cylinder by applying the hydrostatic pressure formula that is given on page 3. Some candidates performed an incorrect calculation that confused the density of the cylinder with the density of the water. A small number of candidates inappropriately gave the final answer to only one significant figure.

(ii) The upthrust could be calculated by two different methods. The simplest and most common method was to multiply the difference in pressure by the cross-sectional area of the cylinder. The other method involved calculating the weight of water displaced by the cylinder. As this was a 'show that' question, it was essential for candidates to carefully present every step of their calculation as well as giving the final answer. Weaker candidates sometimes missed out the step of showing how the area of the cylinder was calculated from its diameter.

(iii) The tension was usually calculated correctly. The most common error was to add the upthrust to the weight instead of subtracting from it.

(b) (i) Answers were usually correct, although some candidates made a power-of-ten error by not converting the unit of velocity from cm s^{-1} to m s^{-1}. Candidates should be encouraged to carefully check the units of graph scales.

(ii) Most candidates realised that the distance moved by the cylinder was equal to the area under the velocity–time graph. However, some candidates found it more difficult to determine the final depth of the cylinder and a common error was adding the distance moved to the initial depth, rather than subtracting from it.

(c) (i) The most common correct answers were 'viscous force' and 'drag force'.

(ii) Although many candidates correctly stated that the acceleration decreases, a significant minority incorrectly stated that there would be deceleration. A significant proportion of the candidates did not explicitly explain that the decrease in acceleration is due to the increase in the viscous force as the cylinder's speed increases. Some candidates simply mentioned that there was a viscous force without explaining the variation of that force.

Question 3

(a) (i) The majority of the candidates correctly calculated the force acting on the spring.

(ii) Most candidates could recall an appropriate symbol expression for the elastic potential energy and then substitute the relevant values into this expression. Some of the weakest candidates confused elastic potential energy with gravitational potential energy.

(b) (i) This question was usually answered correctly. Some candidates inverted the correct ratio of the energy values even though this led to an efficiency that was greater than 100%.

(ii) The vast majority of the candidates could recall the correct symbol formulae for kinetic energy and momentum. Weaker candidates often made an arithmetical error when applying these equations to the question.

(c) (i) The symbol formula for gravitational potential energy was usually stated correctly. When applying this formula, some of the candidates substituted the value of the change in kinetic energy of the ball instead of the value of its change in gravitational potential energy.

(ii) Many candidates realised that the average force of the air resistance could be calculated from the total work done against the air resistance. Only a small proportion of the candidates appreciated that the work done is determined by subtracting the change in gravitational potential energy of the ball from its change in kinetic energy. Many of the weakest candidates simply gave the weight of the ball as their final answer.

(iii) Only the strongest candidates were able to explain that without air resistance the resultant force on the ball is less, so it has less deceleration and therefore takes more time to move to its maximum height. A large number of candidates thought that in the absence of air resistance the ball would move faster and so take less time to reach its maximum height, although this line of reasoning does not consider that the maximum height is now greater.

Question 4

(a) Answers were generally very good, with most candidates showing a clear calculation and answer.

(b) Almost all the candidates could identify at least one correct moment about end A of the plank. However, applying the principle of moments to derive the correct moments equation proved to be more problematic.

Question 5

(a) Almost all the candidates could state the correct wave equation. A power-of-ten error was often made by incorrectly converting the unit of frequency from Hz to GHz. Some of the very weak candidates inappropriately used the speed of sound in their calculation.

(b) (i) The most common incorrect values for the path difference were 0.04 m (corresponding to one wavelength) and 0.06 m (corresponding to one and a half wavelengths).

(ii) Answers to this question were highly varied, often without any correlation to the answer given in **(b)(i)**. The most common incorrect answers were 90° and 360°.

(c) An increase in the intensity was correctly deduced by the majority of candidates. Although many candidates also stated the general relationship between intensity and amplitude, only a small proportion went on to describe the intensity as increasing by a factor of four.

(d) (i) A common misconception was that there would be an increase, rather than a decrease, in the separation between the central intensity maximum and the adjacent intensity minimum. Some candidates did not read the question carefully and attempted to describe changes to the actual intensity rather than to the positions of the central maximum and adjacent minimum.

(ii) A significant proportion of the weaker candidates thought that there would be no maximum or minimum after the change.

Question 6

(a) Candidates who had learnt the required derivation were usually able to present it clearly and concisely. Some candidates omitted the initial equation representing Kirchhoff's first law. Weaker candidates sometimes restated the final formula without any supporting algebra or else confused the required derivation with that for resistors in series.

(b) (i) The current in the battery was usually calculated correctly.

(ii) Some candidates gave the value of the total resistance of the circuit as their answer for the internal resistance. Weaker candidates often incorrectly thought that the current in the internal resistance was equal to the current in resistor X or to the current in resistor Y.

(c) Only a small proportion of the candidates could correctly apply the relevant formula to the question. The most common mistake was using the inverse of the correct current ratio in the calculation.

(d) Weaker candidates often stated incorrectly that the terminal potential difference of the battery would not change. Many of the candidates who correctly deduced that the terminal potential difference would decrease could have improved their answers by giving a more precise supporting explanation. Many candidates needed to improve their understanding of the effect of internal resistance on the terminal potential difference of a battery.

Question 7

(a) The most common correct similarity stated by the candidates was 'equal magnitudes of charge'. The most common correct difference stated by the candidates was 'opposite signs of charge'. Weaker candidates often guessed an answer, with a significant minority incorrectly stating that the quark and antiquark were both leptons. A small minority of candidates inappropriately stated two similarities which ignored the instruction in the question to give only one similarity.

(b) (i) A minority of the candidates wrongly thought that the direction of the electric force on the electron was to the left rather than to the right. This suggests that some candidates are not familiar with the convention for the direction of electric field lines. The weakest candidates sometimes drew a curved arrow which suggested that they were attempting to draw a path rather than the initial direction of the force of the electron.

(ii) Many candidates simply said that the electric force on the electron would cause it to accelerate which does not fully answer the question. A common misconception was that the acceleration is constant because the force is constant. This incorrectly assumes that the electric field is uniform.

(iii) Most candidates realised that the magnitude of the electric force on the α-particle would be larger than the electric force on the electron, although many did not specify that the electric force would be twice as large. A common misconception was that the magnitude of the electric force on a charged particle is dependent upon its mass. Most candidates did not appreciate that a full comparison of the two forces considers their directions as well as their magnitudes.

PHYSICS

Paper 9702/23
AS Level Structured Questions

Key messages

- When answering 'show that' questions, candidates should show all the steps in their calculation as well as giving the final answer. Care should be taken to ensure that any minor steps are not omitted.
- Candidates should use the number of significant figures in the question data as a guide to the number of significant figures required in the final answer. In the majority of cases a minimum of two significant figures is appropriate for the final answer.
- Candidates should pay particular attention to the prefixes of units. If these are ignored or interpreted incorrectly, it can lead to a power-of-ten error in the final answer.
- Candidates should understand the command words that are used in each question. For example, 'state and explain' indicates that an explanation is required as part of the answer in order to obtain full credit. The syllabus contains a glossary of command words.

General comments

In general, the candidates had a good understanding of what was required by each question part. There were many opportunities for weaker candidates to show their understanding in straightforward questions, such as in **Questions 1(a)**, **2(b)(i)**, **4(b)**, **4(c)(i)** and **7(a)**. There were challenging parts for stronger candidates, in particular **Questions 3(e)**, **3(f)**, **4(c)(ii)**, **4(d)**, **5(a)(ii)**, **5(b)(ii)** and **6(d)(ii)**.

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

Comments on specific questions

Question 1

(a) (i) The majority of the candidates were able to give the wavelength with the correct power of ten.

(ii) Most candidates started with the correct formula to determine the frequency for this electromagnetic wave. A minority attempted to use $f = 1 / T$ or use the speed of sound instead of the speed of light. A significant number used the wrong power of ten when converting hertz to terahertz.

(iii) Many candidates wrote the name of a region of the electromagnetic spectrum that did not contain the given wavelength, such as microwave or gamma rays. Some very weak candidates wrote answers that had nothing to do with the electromagnetic spectrum, such as vacuum and electric field.

(b) Most answers were correct. Some candidates confused absolute and fractional uncertainties. The percentage uncertainty in the current was sometimes given as 0.02 or 2% rather than 0.04 or 4%. The majority realised that the percentage uncertainty in I^2 had to be added to the percentage uncertainty in L, but many doubled the percentage uncertainty in L rather than I when calculating the total uncertainty.

Question 2

(a) The majority of the candidates were awarded credit for stating that the centre of gravity is the point associated with the weight of a body. A large number then stated that the point is where all the weight acts rather than where it appears to act. Some candidates inappropriately referred to mass rather than weight.

(b) (i) The majority of the candidates calculated the correct value for the horizontal component of force.

(ii) Most answers were correct. A significant minority used an incorrect distance when taking moments about the end A for either the tension *T* or the horizontal component of the force in the second wire. Some candidates equated the moment for the tension *T* with the horizontal force in the second wire.

(iii) Most candidates gave the correct answer. There were a significant number who gave either just the weight of the post or just the vertical component of the force in the second wire.

Question 3

(a) The majority of candidates applied the appropriate formula correctly. A significant number of candidates did not realise that the vertical and horizontal motion should be treated separately. Some candidates used the initial horizontal speed as the initial vertical speed. There was also some confusion with the signs of the acceleration and the vertical component of the velocity.

(b) Most candidates obtained the correct answer.

(c) Most candidates obtained the correct answer.

(d) A significant minority of candidates sketched graphs with an initial non-zero value for the vertical component of the velocity. Others did not realise that the gradient of the graph represented the acceleration of free fall. There are a minority of candidates who find it difficult to relate a graphical representation to a physical change. It important that candidates have experience of different types of motion, for example speeding up, slowing down, uniform and non-uniform acceleration and understand how these are represented graphically.

(e) Candidates found this question difficult. Some candidates gave their answer to two or four significant figures, even though the question specified the requirement for three significant figures. A common mistake was to confuse the total mass of the cannon and ball with the mass of only the cannon. Some candidates equated the kinetic energies of the cannon and ball rather than their momenta.

(f) Approximately half of the candidates realised that the graph would remain the same, although sometimes their supporting explanation was not correct. Some candidates referred to the velocity increasing because of the lower mass of the ball, without realising that this refers to the horizontal and not the vertical component of velocity. A number of candidates incorrectly referred to reduced air resistance despite the question stating that the air resistance was still negligible. There were many confusing statements made inferring that the velocity was constant whilst acceleration was constant, which seemed to be a common misunderstanding. In general, many candidates were unclear about the independence of vertical and horizontal motion in relation to projectiles.

Question 4

(a) The majority of the candidates gave a correct response. A small minority gave a symbol equation without explaining all of the symbols. Others incorrectly described the force as a resultant force being proportional to the extension, which is incorrect.

(b) Most answers were correct.

(c) (i) Most candidates calculated the speed correctly.

(ii) Stronger candidates were able to calculate the kinetic energy at the top of the loop by subtracting the change in gravitational potential energy from the initial kinetic energy. Weaker candidates often incorrectly assumed that the change in gravitational potential energy was equal to the kinetic energy at the top of the loop.

(iii) The majority of the candidates gave the correct answer. A significant minority did not realise that the speed at Y would be the same as the speed at X due to conservation of energy. A variety of wrong speeds were seen, mostly derived from inappropriate amounts of kinetic energy or inappropriate uses of the equations representing uniformly accelerated motion.

(d) A common mistake was to inappropriately subtract the change in kinetic energy from the elastic potential energy and then use the result as the work done against the resistive force. Some candidates calculated the total distance incorrectly, often using an incorrect formula for the circumference of the loop.

Question 5

(a) (i) The majority of the candidates calculated the correct frequency. There were a significant number that determined the incorrect time period from the trace, often using 3.0 cm instead of 6.0 cm in their calculation.

(ii) Most candidates tried to draw a trace with the same period, although often without enough attention to detail. Candidates should be reminded that the accurate sketching of graphs is important. The amplitude was often drawn double the original amplitude.

(iii) Only a small minority of the candidates gave the correct answer. Many described changes to the sinusoidal trace that implied the time-base was still switched on. Others stated that the trace would be a straight line, but did not say that this line was vertical. A large number of candidates incorrectly stated that the trace would be a horizontal line. A significant number gave no response.

(b) (i) The majority of answers were correct. Common mistakes included confusing the line spacing with the number of lines per unit length and substituting an angle of 32° instead of 16° into the relevant symbol equation. Some candidates substituted $n = 1$ instead of $n = 2$.

(ii) Most candidates were able to determine the highest order by substituting an angle of 90° into the relevant symbol equation.

Question 6

(a) Candidates found it difficult to recall the required definition with sufficient precision. Many candidates made the correct reference to energy transfer, but many did not include the 'per unit charge' part of the definition.

(b) The majority of the candidates were able to recall the relevant symbol formula. Stronger candidates were then able to relate the length to the volume and cross-sectional area. Some of the weaker candidates thought that the symbol for resistivity represented density.

(c) Most candidates gave a correct response.

(d) (i) Most candidates calculated the correct power. Weaker candidates could usually recall a correct equation for electrical power, but sometimes substituted an incorrect current of 0.5 A or an inappropriate value for the resistance of the variable resistor.

(ii) Weaker candidates were sometimes unable to determine the internal resistance from the *y*-intercept of the graph. Most candidates correctly calculated the e.m.f. of the battery by using the values that they had obtained from the previous parts of this question. Very few candidates realised that they could use the gradient of the graph to directly determine the e.m.f. Weaker candidates often confused the potential difference across the variable resistor with the e.m.f. of the battery.

Question 7

(a) (i) Most candidates gave the correct answer.

(ii) Most candidates gave the correct answer.

(iii) Most answers were correct, although candidates found this part of the question more difficult than the previous two parts.

(b) (i) Although most answers were correct, many weaker candidates were unable to apply the relationships given in **(a)**.

(ii) Only a minority of candidates gave the correct answer. Candidates needed to realise that isotopes will have the same charge but a different mass. Many candidates found it difficult to apply the relationships given in **(a)** where the charge remained the same but the mass was reduced.

(c) (i) Most candidates gave the correct answer.

(ii) Most candidates gave the correct answer.

PHYSICS

Paper 9702/31
Advanced Practical Skills 1

Key messages

- Candidates should be encouraged to ask themselves whether the answer provided looks right e.g. in the case of recording the distance *p* in **1 (b)** or measuring θ in **2 (a)(i)** or *t* in **2 (b)(i)**.
- Candidates need to remember to state their recorded measurements to the precision of their measuring instruments e.g. ruler used for measuring the distance *p* in **1(a)** to the nearest 0.1 cm, protractor used for measuring angles in **2(a)(i)** to the nearest degree.
- Candidates should then be encouraged to undertake repeated readings (at least two) especially if a time is asked for. Each raw reading should have the same precision.

General comments

There was no evidence that centres had 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 so that full benefit can be given to the candidate where necessary.

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 all candidates. They demonstrated good skills in the generation and handling of data but can improve by giving more thought to the evaluation of experiments.

Comments on specific questions

Question 1

(a) Most candidates stated a value for *p* in range and with a consistent unit. Some candidates omitted the unit or measured a value that was too large.

(b) Most candidates stated *m* in range.

(c) Most candidates were able to collect six sets of values of *m* and *p* without assistance from the Supervisor. A minority of candidates collected more results. A few candidates collected five or fewer.

Some candidates extended their range of mass of water to either 80 g or more. Other candidates fell just short of this range. Candidates are encouraged to use the full limit possible with the apparatus provided.

Many candidates were awarded credit for the column headings, stating the quantity and correct unit. The $\sqrt{m}$ and $\sqrt{p}$ column heading unit was sometimes incorrectly stated as g and cm respectively. A few candidates omitted either the unit or the separating mark for one or more of the columns. The heading and the unit should be separated by a solidus or by using brackets around the unit. Most candidates calculated √p correctly.

Many candidates correctly recorded their raw values for *p* to the nearest 0.1 cm. Some candidates stated *p* to the nearest cm (e.g. 10 cm) without considering that they can make the measurement to the nearest mm using the ruler provided. Some candidates added a trailing zero to the end of their number if it was less than 10.0 cm so that the number of significant figures was the same down the column (e.g. 15.0, 9.00, 5.00 cm). This was penalised as the number of decimal places in the raw readings of *p* must reflect the precision of the ruler used (i.e. 9.0 cm and 5.0 cm). As the ruler measuring *p* can be read to the nearest mm, the number of decimal places in *p* must be consistent down all raw data columns and not the number of significant figures. The calculated values of √*m* where mostly given to the same number of significant figures as at that used in *p* by most candidates. A few gave too few significant figures.

The table work was done well by candidates. The range mark was the most difficult mark to obtain.

(d) (i) A few candidates omitted labels or marked their scales with every four large squares (axes gaps). Some candidates plotted *p* instead of √p even though the label was √*p*. Compressed scales (i.e. plots occupy less than four large squares in the *x* direction or less than six large squares in the *y* direction) were seen often and failed to gain credit. This may have arisen because of the candidate's perceived need to start the graph at the origin. There were many incidences of awkward scales (e.g. based on 3 or 12). A few 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 for both the candidate and the Examiner and often leading the candidate to run out of time to complete the last section of the question. Awkward scales cannot be awarded credit and it was very common for candidates using such scales to lose further credit for subsequent incorrect read-offs. A few candidates just labelled the scale markings with their point readings from the table which failed to gain credit. A few candidates used non-linear scales and having failed to gain credit for the axes, the quality mark was also not awarded as the error was often in the region of the plotted points. Candidates should be encouraged to check their scales for linearity as they can lose two marks for missing out a scale marking unintentionally. 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 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 drawing the line of best fit, the anomalous point should be labelled clearly e.g. by circling the point. If two or more points are identified as anomalous then all the points drawn are considered in the Examiner's judgement of the line of best fit mark. 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, but 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 of the drawn line of best fit. Many lines needed rotation to give 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 (candidates used too small a ruler), a double line (broken pencil tip) 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 $\Delta y/\Delta x$. 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). 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, if used, $m(x - x_1) = (y - y_1)$ should be shown with substitution of read-offs.

As in previous years, there were many instances of incorrect read-offs, and many candidates would benefit from double-checking their read-offs. Instead of read-offs, some candidates used table points that were not on their line and this was not credited.

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. Some candidates rearranged this equation incorrectly before substituting their numbers (i.e. $y/mx = c$). Others needed to check that the point chosen (if it was from the table) was on the line drawn.

(e) Many candidates recognised that *A* was equal to the gradient and *B* was equal to *y*- intercept calculated in **(d)(iii)**. Some candidates omitted units for *A* and/or *B*. Some candidates stated incorrect units for *A* (e.g. cm g^{-1}) and/or for *B* (e.g. cm).

Question 2

(a) (i) Most candidates stated a value for θ in range to the nearest degree. A few candidates misread the protractor and stated a value above 90°. Some candidates stated the measurement to the nearest 0.1 degree failing to gain credit as the precision of the protractor is to the nearest degree.

(ii) Many candidates correctly calculated $\sin\theta$. Some candidates truncated their answer instead of rounding correctly.

(iii) Most candidates correctly justified the number of significant figures they had given for the value of $\sin\theta$ with reference to the number of significant figures used in their initial angle measurement.

(b) (i) Some candidates stated repeated values of *t* with the final value in range. Many candidates failed to repeat their time or show any evidence that repeats were carried out by writing them down. Some candidates stated too high a number for *t* misreading the timer. Candidates should be encouraged to look back at their answers and ask themselves whether it is realistic.

(ii) Many candidates are familiar with the equation for calculating percentage uncertainty and gave an uncertainty in *t* that was in the range deemed acceptable for this experiment given the inherent difficulties in taking the measurements involved. Some candidates made too small an estimate of the absolute uncertainty in the value of *t*, typically 0.1 s or 0.01 s. Some candidates used the uncertainty of 0.01 s from the precision of the timer without considering the reaction time. Some candidates having repeated their times in the previous question proceeded to correctly calculate half the range in the time values for the uncertainty, whilst other candidates forgot to halve the range.

(c) (i) Most candidates recorded a second value of θ and correctly calculated $\sin\theta$.

(ii) Most candidates recorded a second value of *t* which was more than their first value of *t*.

(d) (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 and calculated $t/\sin\theta$ 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 per cent, 15 per cent, 20 per cent or the percentage uncertainty calculated for *t*. Some candidates omitted a criterion or referred to ‘percentage uncertainty’ without making it clear they meant the percentage uncertainty for *t* or gave a vague statement such as ‘this is valid because the values are close to each other’ or ‘strongly supported’ without any working. Occasionally candidates gave a contradictory statement such as ‘my results do not support this relationship as my per cent difference is less than 10 per cent’.

(e) 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. Careful use of language was needed here as some candidates stated two readings were not enough to ‘conclude’ (to end the experiment) instead of meaning to reach a conclusion or candidates referred to taking results rather than drawing a conclusion. 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 measurement e.g. θ and *t*. Various reasons for the difficulty in measuring *t* and θ were provided. Solutions credited often were video the motion with a timer.

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'. Unrealistic solutions were also not given credit, e.g. 'robotic arm' or 'mechanical hand' to hold and release the cardboard shape. Limitations that were irrelevant or that could have been removed if the candidate had taken greater care were not given credit e.g. parallax error. Vague or generic answers did not gain credit such as 'too few readings' (without stating a consequence).

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

PHYSICS

Paper 9702/33
Advanced Practical Skills 1

Key messages

- Candidates should be encouraged to ask themselves whether the answer they have provided after a measurement or calculation has the right order of magnitude, as this can help detect mistakes in recording measurements or in calculations.

- Candidates need to remember to state their recorded measurements to the precision of the measuring instruments, e.g. vernier calipers can be read to the nearest 0.01 cm and metre rules to the nearest 1 mm.

- Candidates should take repeated readings, especially if a measurement could be subject to random error, e.g. measuring a time or a diameter. In the case of determining the period of an oscillation, candidates should measure the time for several oscillations **and** repeat this measurement.

- In answering **Question 2**, candidates should be reminded that limitations and suggestions for improvement must be focused on the experiment. General points such as 'avoid parallax error' or 'use more precise measuring instruments' or 'use better apparatus' will not gain credit without further detail. As candidates take measurements, they should ask themselves 'why is this measurement difficult to take?' and then 'is there a better method I could use to take this measurement accurately?'

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) Stronger candidates repeated measurements of the diameter and provided a final value with an appropriate precision. Many candidates did not repeat the measurement, stated a less precise value (e.g. to the nearest mm) or gave a value that was out of range by a factor of ten such as 5.0 mm.

(b) Many candidates measured *p* and *F* correctly. A minority of candidates stated *p* as 37.0 cm instead of the expected 17.0 cm, indicating that they had omitted to take the 20.0 cm from the end of the ruler away. A minority of candidates stated their newton meter reading *F* in grams instead of newtons.

(c) Most candidates were able to collect six sets of values of *p* and *F* without assistance. A minority of candidates collected more results. Very few candidates collected five or fewer.

Many candidates did not reduce their *p* value from 17.0 cm and so did not make full use of the range of values available. It was expected that candidates make use of the whole available range.

Many candidates were awarded credit for the column headings, stating the quantity and correct unit. The ($p + r$) column heading unit was sometimes incorrectly stated as cm + cm, cm^2, 2 cm or N + cm instead of just cm. Some candidates omitted either the unit or the separating mark for one or both of the columns. Most candidates calculated ($p + r$) correctly. A few candidates calculated ($p + F$) or ($F + r$) instead.

Many candidates correctly recorded their raw values for *p* to the nearest 0.1 cm and *F* to the nearest 0.1 N. Some candidates incorrectly stated *p* to the nearest cm or the force to the nearest 0.01 N. Some candidates added on a trailing zero to the end of their number if it was less than 10.0 cm to make the number of significant figures the same down the column (e.g. 15.0, 9.00, 5.00 cm). This is not awarded credit as the number of decimal places in the raw readings of *p* must reflect the precision of the ruler used.

(d) (i) Some candidates omitted labels or marked their scales with large gaps between the labels (more than three large squares). Compressed scales (where the plotted points occupy less than four large squares in the *x* or less than six large squares in the *y* direction) were often seen and also did not gain credit. This may have arisen because of the candidate's perceived need to start the graph at the origin. There were many incidences of awkward scales (e.g. based on 3 or 12).

A few weaker 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 with subsequent read-offs.

Some candidates labelled the scale markings with their readings from the table and this cannot gain credit. A few candidates used non-linear scales. Graphs with non-linear scales cannot be given credit either for the axes or for the quality of data if the points are plotted in the part of the scale that is non-linear. Candidates should be encouraged to check their scales for linearity.

Some points were drawn as dots with a diameter greater than half a small square, or 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. 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.

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) Many candidates recognised that *Q* was equal to 3.00 / gradient and *S* was equal to *y*-intercept × *Q*. Some candidates incorrectly stated that *Q* was equal to the gradient and *S* was equal to the intercept. Weaker candidates often omitted units for *Q* and/or *S*, or gave incorrect units for *Q* such as N cm^{-1} or cm^{-1}.

Question 2

(a) (i) Most candidates measured values of *L* in the correct range and gave a final value to the nearest mm. Some candidates stated the measurement to the nearest 1 cm or 0.1 mm.

(ii) Many candidates are familiar with the equation for calculating percentage uncertainty and gave an uncertainty in *L* that was in the range deemed reasonable for this experiment given the inherent difficulties in taking the measurements involved. Some candidates made too small an estimate of the absolute uncertainty in the value of *L*, typically 1 mm, or too large an estimate, typically 1.0 cm. Many candidates just used the uncertainty of 1 mm from the precision of the measuring instrument. Some candidates repeated their readings and correctly gave the uncertainty in *L* as half the range, although other candidates did not halve the range when using this method.

(b) (i) Most candidates stated values of *T* with the correct precision and showed evidence of repeats of more than one set of oscillations. Many candidates did not repeat sets of oscillations. Some candidates were not awarded credit because they did not state the number of oscillations they were timing and provided a final answer outside the permissible range.

Candidates should be encouraged to look back at their answers and ask themselves whether they are realistic: a time of 6 s for one period is very long, for example. Some candidates provided a single value of *T* without any working. A few candidates confused the period with the frequency and, having found *T*, then calculated the frequency and stated this as their final answer for *T*.

(ii) Many candidates correctly calculated T^2. Some candidates truncated their answer instead of rounding correctly.

(iii) Candidates found it difficult to justify the number of significant figures they had given for the value of T^2 with reference to the number of significant figures used in their initial time for nT oscillations. Many candidates stated either 'raw readings' or *T* without making reference to what the raw quantity actually was, or incorrectly involved *L* in their justification.

(c) Most candidates recorded second values of *L* and *T* which were both less than their first values of *L* and *T*.

(d) (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 or inadvertently substituted the wrong values.

(ii) The stronger 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*. 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. Occasionally candidates gave a contradictory statement such as 'my results do not support this relationship as my % difference is less than 10%'.

(e) Only the strongest candidates obtained a realistic value of *g*. Many others forgot to convert their *k* value from $cm\,s^{-2}$ into $m\,s^{-2}$ and obtained values in excess of $1000\,m\,s^{-2}$. A check here on whether the answer looks reasonable might have revealed that an error had been made.

(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. Careful use of language was needed here; some candidates referred to taking results rather than drawing a conclusion. 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 measurements.

Various reasons for difficulty in measuring *L* were given, such as the wire not being straight or having rounded corners. Also commonly seen were limitations relating to measuring *nT* because it is difficult to judge the end of the oscillation. Solutions that were often seen and credited were to video the oscillations with a timer and to use a stiffer wire.

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', 'mechanical hand' to hold and release the wire square, or using a fiducial marker placed at the end of the oscillation (instead of in the middle). Limitations that were irrelevant or that could have been removed if the candidate had taken greater care were also not given credit. Vague or generic answers such as 'too few readings' (without stating a consequence) or 'use a set square/protractor' (without stating what these would be used for) also cannot be given credit.

The key to this section is for candidates to identify genuine problems associated with setting up this experiment and in obtaining readings. Candidates are 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

- Candidates should be encouraged to ask themselves whether the answer they have provided after a measurement or calculation has the right order of magnitude, as this can help detect mistakes in recording measurements or in calculations.
- Candidates need to remember to state their recorded measurements to the precision of the measuring instruments, e.g. vernier calipers can be read to the nearest 0.01 cm and metre rules to the nearest 1 mm.
- Candidates should take repeated readings, especially if a measurement could be subject to random error, e.g. measuring a time or a diameter. In the case of determining the period of an oscillation, candidates should measure the time for several oscillations **and** repeat this measurement.
- In answering **Question 2**, candidates should be reminded that limitations and suggestions for improvement must be focused on the experiment. General points such as 'avoid parallax error' or 'use more precise measuring instruments' or 'use better apparatus' will not gain credit without further detail. As candidates take measurements, they should ask themselves 'why is this measurement difficult to take?' and then 'is there a better method I could use to take this measurement accurately?'

General comments

There was no evidence that centres had particular difficulties in providing the equipment required for use by the candidates. Some centres were unable to supply the specified washers for **Question 2** and so suitable alternatives were sourced. Details of these changes were helpfully recorded on the Supervisor's Report. When this information is provided, candidates who have recorded readings that are outside of the expected range can still be given credit where appropriate.

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 work carried out by the candidates was good, with many producing excellent scripts. Working was usually clear and legible. Candidates should be encouraged to draw tables carefully using ruled lines and, where possible, record data systematically. For graph work, candidates should be encouraged to use a 30 cm ruler to draw lines of best fit and to provide legible scale markings on axes.

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) Most candidates recorded a value for x that was within the expected range. Answers were generally provided to the correct precision (nearest mm). Candidates who were not awarded credit often gave their answer (or raw data where seen) to the nearest cm.

(b) The majority of candidates recorded a value for θ that was within the expected range or, if outside of range, suitably close to the Supervisor's value when compared. A small number did not record their values to the nearest degree.

(c) The majority of candidates were able to collect six sets of x and θ without help from the Supervisor. In a small number of cases the expected trend was not observed. This was possibly due to using the wrong scale on the protractor. Most tables were neatly presented and legible.

Stronger candidates tested a full range of x values, including $x \leqslant 20.0$ cm and $x \geqslant 40.0$ cm. A significant number of candidates only included values of x less than 40.0 cm and so were not awarded credit for the range.

Table headings were generally correct and presented using accepted scientific convention. One common error was the omission of a suitable separating mark between the quantity and unit, for example writing $\theta\,°$ instead of $\theta/°$ or $\theta\,(°)$. Another common error was in providing a unit for the quantity cos θ.

Most candidates correctly recorded all values of θ to the nearest degree. A small number of candidates chose to record all θ values to the same number of significant figures and so incorrectly added a decimal place to account for the change from three digit to two digit θ values, e.g. recording 65° as 65.0°. Since this is measured data, it was then not consistent with the precision of the protractor.

Most candidates recognised that values of cos θ should be recorded to the same number of significant figures (or one more than) the number of significant figures in the corresponding value of θ. It is worth noting that consistency down the column may not be appropriate. For example, if θ in one row is 9°, cos θ in that row should have 1 or 2 significant figures whereas another row may have a value for θ of 126° and so cos θ would be recorded to 3 or 4 significant figures.

Most calculations were correct. A small number of candidates made rounding errors or calculated a different quantity e.g. sin θ.

(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. Although most candidates coped well with a mixture of positive and negative values, a few candidates had difficulty with plotting and scales (e.g. backwards scales used where values were negative).

Any data recorded in the table must be plotted on the graph. Candidates who used small crosses or small circled dots produced the clearest plotted points. The use of large dots (with diameters greater than 1 mm) is not awarded credit because their accuracy cannot be judged. Some candidates identified their own plotting errors as anomalies. Candidates should be encouraged to double-check such points.

The quality of the candidates' data was judged by the scatter of points about a straight-line trend. In the majority of cases this was good and so credit was awarded.

(ii) Many candidates produced suitable lines of best fit which had a balanced distribution of points either side along the entire length. Some candidates appeared to ignore an anomalous point but did not show that this is what they had done, and others ignored a seemingly good point when drawing the line. Candidates must label a point as anomalous if they intend to ignore it when plotting the line of best fit. There is no need to ignore a point if none of the points appears to be anomalous.

(iii) When calculating the gradient of their line, most candidates selected suitable points on the line (greater than half of the length of the line apart) and substituted correct read-off values into $\Delta y / \Delta x$. Points chosen were clearly identified on the graph; usually as a drawn triangle. Of those candidates who were not awarded credit, most had incorrectly determined the read-off values or used points from the table that were not within half a small square from the line. Others used triangles that were too small.

When selecting scales for the graph, the nature of the data meant that many candidates started their *x*-axis with a non-zero value. Most candidates recognised that it was therefore not possible to take a direct read-off to determine the *y*-intercept. Most candidates substituted correct values from their line into $y = mx + c$ to arrive at their answer. Some candidates incorrectly quoted the *y*-axis value at the point where the line crossed, even though this was not at $x = 0$.

(e) The majority of candidates recognised that *a* was equal to their gradient value and that *b* was equal to their *y*-intercept value. Some candidates were able to provide correct units for *a* and recognised that *b* had no units. A significant number of candidates either omitted units or included units for $\cos\theta$ when determining the units of *a* and *b*.

Some candidates presented their answer to only one significant figure and were not awarded credit.

Question 2

(a) (i) Almost all candidates recorded a final value for *x* that was within the expected range and with a correct unit. Most raw values were recorded to the nearest mm, correctly matching the precision of the ruler used. Some candidates provided raw values to the nearest cm and so were not awarded credit.

(ii) The majority of candidates provided raw values of *D* and *d* in range and to the nearest mm. It appeared that some candidates had measured the radius rather than diameter of the washer, leading to a value outside of the expected range.

(iii) Most candidates correctly used their values of *x*, *D* and *d* to calculate *L*. Almost all candidates ensured that their values of *D* and *d* were in the same units when subtracting. A small number incorrectly rounded their final answer.

(iv) Stronger candidates linked the number of significant figures in *L* with the number of significant figures in *x*, *D* and ($D – d$). Many candidates did not directly reference the quantities used in the calculation of *L*, instead referring to unspecified ‘raw data’ or ‘previous values’.

(b) (i) Many candidates recognised that measurements of time should be repeated. Most candidates recorded consistent data (i.e. all raw values to the nearest 0.1 s or all raw values to the nearest 0.01 s) and provided a final value of *T* within the expected range. Some candidates were not awarded full credit because they did not record repeat readings, or provided a final value based on *nT* instead of *T*.

(ii) Most candidates were familiar with the equation for determining percentage uncertainty. Candidates found it difficult to suggest a suitable value for the absolute uncertainty in *T*, often using 0.1 s or the precision of the stop-watch (0.01 s). Considering the nature of this experiment, these estimates are too low. A value of between 0.2 s to 0.5 s was acceptable for the absolute uncertainty.

(c) Most candidates recorded second values of *x* and *T* with the second value of *T* being greater than the first.

(d) (i) Although the majority of candidates were able to manipulate the equation to arrive at correct values of *k*, some had problems with the rearrangement or forgot to square *T*.

(ii) Many candidates were able to arrive at a correct conclusion by testing against a stated criterion. Clear answers contained a suitable method for calculating the percentage difference between their *k* values, the outcome of which was compared with a stated numerical criterion of their choosing.

Some candidates were not awarded credit because their criterion was not clearly stated (e.g. they referred to 'percentage uncertainty' without specific reference to *T* or the value in **(b)(ii)**).

(e) Stronger candidates made appropriate unit adjustments to arrive at a value of *g* in $m\,s^{-2}$. A large number of candidates did not correctly convert the units (e.g. *k* values were derived from values of *L* and *x* in cm) and the resulting value of *g* contained power-of-ten errors. A small number of candidates recognised this error and made subsequent adjustments to the final answer. Candidates should be encouraged to check their working if the final value seems to be outside the range that would be expected.

(f) For both the limitations and improvements, candidates are advised, where appropriate, to state both the quantity being measured and the reason for any uncertainty. Many candidates gave partial statements in one or more of their responses and so were unable to gain credit for these. A good answer, for example, would be 'there is an uncertainty in *T* because it is difficult to judge the end of an oscillation': a difficulty is identified and the candidate specifies which measurement is affected.

For the limitations, the majority of candidates recognised that calculating two values of *k* is insufficient to draw a conclusion. Some candidates incorrectly linked the lack of *k* values to accuracy whereas others gave insufficient statements such as 'two *k* values are not enough'.

A significant number of candidates recognised that the number of measurable oscillations was limited (due to damping) as well as identifying problems with the apparatus sliding down the board. There were many good answers referring to the difficulties in measuring the diameters of the washers or *x* (e.g. parallax, the nuts/bolt preventing proper placement of the ruler etc.).

Very few candidates gave an acceptable reason for uncertainty in θ (i.e. that the angle is small and so the uncertainty is large). Many suggested that it was difficult to measure the angle using the protractor as the zero could not be aligned with the surface of the bench. This was not accepted as it is possible to measure the angle of the board at any height above the bench.

For improvements, many candidates correctly suggested taking more readings and plotting a graph. Other good answers included using calipers or a micrometer for measuring *x* or washer diameters and using a video with a timer to record *T*.

PHYSICS

Paper 9702/35
Advanced Practical Skills 1

Key messages

- Candidates should be encouraged to ask themselves whether the answer they have provided after a measurement or calculation has the right order of magnitude, as this can help detect mistakes in recording measurements or in calculations.

- Candidates need to remember to state their recorded measurements to the precision of the measuring instruments, e.g. vernier calipers can be read to the nearest 0.01 cm and metre rules to the nearest 1 mm.

- Candidates should take repeated readings, especially if a measurement could be subject to random error, e.g. measuring a time or a diameter. In the case of determining the period of an oscillation, candidates should measure the time for several oscillations **and** repeat this measurement.

- In answering **Question 2**, candidates should be reminded that limitations and suggestions for improvement must be focused on the experiment. General points such as 'avoid parallax error' or 'use more precise measuring instruments' or 'use better apparatus' will not gain credit without further detail. As candidates take measurements, they should ask themselves 'why is this measurement difficult to take?' and then 'is there a better method I could use to take this measurement accurately?'

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 the value of I to the nearest 0.1 mA with a correct unit and set up the apparatus correctly so that I was in the allowed range. Some candidates omitted units or gave 30.0 A rather than 30.0 mA, having misread the ammeter.

(b) Many candidates were able to collect six sets of values of R and I without assistance, and showed a correct trend in their values. A minority of candidates took extra sets of results and then did not plot all their observations on the graph grid. Only a small number of candidates took the time to repeat their readings. Repeating readings may have helped to identify anomalous results and improve data quality. If time is limited, candidates should be encouraged to look out for possible outliers which do not fit the general trend and repeat these readings to double-check them.

Values of resistance were provided for candidates and readings should be taken for the lowest and highest possible values of resistance. Many candidates omitted either 204 Ω or 22.7 Ω. It is expected that candidates use the whole range of resistances available.

Many candidates were awarded credit for the column heading, giving both the quantity and correct unit for each heading with both separated by a solidus or with the unit in brackets. Some candidates omitted either the unit or the separating mark for one of the columns.

Many candidates correctly recorded their raw values for I to the nearest 0.1 mA. Some candidates stated their measurement to the nearest mA e.g. 35 mA without considering that they can read to the nearest 0.1 mA using the meter.

Many candidates recorded their calculated values for $1/I$ to the correct number of significant figures, i.e. to the same number of significant figures as (or one more than) the number of significant figures in the raw values of I. Some candidates either stated too many or too few significant figures, or aimed to be consistent in their use of decimal places at the expense of significant figures. This often increased the amount of scatter in the results plotted on the grid.

Most candidates calculated values for $1/I$ correctly. A few candidates rounded their final answers incorrectly, including rounding to only one significant figure.

In general, the table work was done well by candidates. Candidates who sought the help of the Supervisor in setting up the apparatus were usually able to gain credit for the table.

(c) (i) Candidates were required to plot a graph of $1/I$ on the *y*-axis against R on the *x*-axis. Many candidates plotted points carefully using a sharp pencil and chose a good line of best fit.

Candidates could improve by ensuring scales (in either the *x* or *y* direction) are chosen to spread out plotted points to occupy the whole of the graph grid, rather than points being squashed into a small part of the grid. A few weaker 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 with subsequent read-offs.

Some candidates used irregular (i.e. non-linear) scales. Irregular scales could not be given credit, and often the data could not be awarded credit for quality either because the error was often in the region of the plotted points. Candidates should be encouraged to set up their graphs to make them easy to work with in later parts of the question.

Candidates need to draw points with a diameter equal to or less than half a small square. They can improve by carefully checking that points are plotted in the correct position. Some candidates plotted the point for R = 204 Ω on the edge of the grid corresponding to R = 200 Ω and credit could not be given.

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. 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) Many 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.

Candidates should be encouraged to draw the line according to the positions of the plotted points, and not to force the line through the origin.

(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.

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 $R = 0$ 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) Many candidates recognised that some calculation was needed to determine values of E and X. Some candidates falsely assumed that the question was the same as some in previous papers where the constants were equal to the gradient and the intercept, and consequently could not be awarded credit.

Stronger candidates recorded values with consistent units for E and X. Weaker candidates often stated incorrect units or omitted the units.

Question 2

(a) (i) The ruler provided to make the measurements had a precision of 1 mm. Many candidates were able to accurately measure and record the dimensions of the card to the nearest mm. To improve, some candidates need to record values to the nearest mm rather than to the nearest cm and other candidates need to resist the temptation to add extra zeros to their readings (e.g. recording 21.2 cm as 21.20 cm).

(ii) Many candidates correctly calculated $2q / (p + q)$. Some candidates incorrectly rounded their final value. A minority of candidates incorrectly used the w value rather than the p value.

(b) (i) Most candidates measured a value of d.

(ii) Most candidates are familiar with the equation for calculating percentage uncertainty. Some candidates made too small an estimate of the absolute uncertainty in the value of d by choosing to use the smallest division on the ruler i.e. 1 mm. Some candidates repeated their readings and correctly gave the uncertainty in d as half the range, while other candidates did not halve the range.

(iii) Most candidates correctly used their w and d values to calculate $(w - d)$.

(c) (i) Many candidates noted the word ‘accurately’ in the question and gave plenty of detail. Some candidates could improve by ensuring they write a detailed method.

(ii) Using the ruler again dictated that the measurement of q should be given to the nearest mm. Many candidates recorded the value of q to the nearest mm having accurately halved the length of the card.

(iii) Most candidates recorded a second d value which was greater than their first value.

(d)(i) Many 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 chose to round, giving their final answer to only one significant figure.

(ii) Many 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% or 20%. Some candidates referred back to the percentage uncertainty calculated for d and this was also credited. Some candidates omitted a criterion. Other candidates gave a general statement such as 'this is valid because the values are close to each other' which was not credited as there was no justification for the conclusion.

(e) This experiment provided many limitations and improvements to write about, ranging from the measurements to the practical difficulties of setting up the card and taking readings. Many candidates recognised how difficult it was to use the paper clip to suspend the card, and also that it was difficult to pinpoint the centre of the paper clip and difficult to judge when the card was exactly horizontal when suspended. Having recognised these difficulties, candidates gave detailed descriptions of the difficulties with detailed suggestions of how to improve the measurements.

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 candidates stated 'two readings is not enough to draw a graph' which did not have enough detail either as a limitation or as an improvement. To gain credit for limitations concerning measurements, candidates need to provide sufficient detail. For example, 'it was difficult to know where the centre of the paper clip is as the paper clip does not have a regular shape'.

Some candidates gave problems that were irrelevant or that could have been avoided if the candidate had taken greater care. Vague or generic answers such as 'too few readings' (without stating a consequence), 'faulty apparatus' or 'unstable stand' do not gain credit. Similarly, vague improvements such as 'keep eye level' or 'use a better cutter' or 'laser cutter' could not be awarded 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 9702/36
Advanced Practical Skills 2

Key messages

- Candidates should be encouraged to ask themselves whether the answer they have provided after a measurement or calculation has the right order of magnitude, as this can help detect mistakes in recording measurements or in calculations.
- Candidates need to remember to state their recorded measurements to the precision of the measuring instruments, e.g. vernier calipers can be read to the nearest 0.01 cm and metre rules to the nearest 1 mm.
- Candidates should take repeated readings, especially if a measurement could be subject to random error, e.g. measuring a time or a diameter. In the case of determining the period of an oscillation, candidates should measure the time for several oscillations **and** repeat this measurement.
- In answering **Question 2**, candidates should be reminded that limitations and suggestions for improvement must be focused on the experiment. General points such as ‘avoid parallax error’ or ‘use more precise measuring instruments’ or ‘use better apparatus’ will not gain credit without further detail. As candidates take measurements, they should ask themselves ‘why is this measurement difficult to take?’ and then ‘is there a better method I could use to take this measurement accurately?’

General comments

There was no evidence that centres had difficulty in providing the equipment required for the two experiments. There did not seem to be a shortage of time and all sections of the two questions were answered by nearly all candidates.

The Supervisor’s Reports from many centres included useful detail about difficulties encountered in the experiments and any help provided or extra time allowed. This information 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. Some candidates’ full working was not shown or was difficult to read. Where a value is changed, it should be crossed out neatly with the new value written above.

Comments on specific questions

Question 1

(a) Candidates were asked to find the initial balance point, and most recorded a value of *y* in the expected range for a correctly constructed circuit.

(b) Most results tables contained six or more sets of values. In a few cases the trend was wrong, possibly caused by a reversed metre rule scale. Stronger candidates included the largest and smallest resistance values provided to give the widest possible range of readings. In some cases, the smallest resistance value was not included in the table even though it had been used in **(a)**, and this meant that the full data range was not shown in the graph.

Tables from most candidates were neat and clear. Most headings included a correct unit with clear separation from its quantity. For $1/y$ the unit was sometimes given for y (i.e. cm) rather than for the whole quantity (cm^{-1}).

The majority of the candidates recorded their y values to the nearest mm and in most cases the calculation of $1/y$ was correct, apart from a small number of rounding errors. Stronger candidates were also credited for using a suitable number of significant figures in their calculated quantities.

(c) (i) The general standard of graphs was very good. The best graphs 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, and each axis was labelled with the plotted quantity.

Small crosses generally produce the clearest plotted points as long as the pencil is sharp. The use of large dots (with diameter greater than 1 mm) is not awarded credit because the accuracy of their position cannot be judged.

The quality of the candidates' data was judged by the scatter of points about a straight-line trend. In the majority of cases this was good and so credit was awarded.

It is worth noting that where y was small (e.g. 9.5 cm) the calculated value $1/y$ could be given to either three significant figures ($0.105\,cm^{-1}$) or to two significant figures ($0.11\,cm^{-1}$). On the graph grid these two positions would probably differ by five small squares, so the more precise choice would give less chance of excessive scatter.

(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 not ignore more than one point in this way.

Some candidates were not awarded credit for their line because of using a short ruler and having to extend their line to cover the range of their plotted points. Kinks and joins in the line are often apparent in such cases.

(iii) Nearly all candidates knew how to find the gradient of their line. A few made errors such as using the coordinates of plotted points that were not on their line, or used points that were on the line but were too close together.

Most candidates calculated their intercept value, but some tried to read it directly from the $1/y$ axis without checking that the R axis started from zero.

(d) Most candidates recognised that a was equal to the value of the gradient and b was equal to the intercept. A common error was to give a or b to only 1 significant figure. A large number of candidates included correct units for their a and b values.

(e) (i) Nearly all candidates recorded a sensible value for the length W, although a few recorded it only to the nearest cm.

(ii) Most candidates went on to calculate P correctly after checking that the length units were compatible. Candidates must remember that all the lengths need the same unit before carrying out this type of calculation. For example, if a was determined in $\Omega^{-1}\,m^{-1}$, then a value of W in metres should be substituted when determining P.

Question 2

(a) The initial measurements of L and H were made with the second ruler. Most candidates correctly recorded their measurements to the nearest mm.

(b) Stronger candidates realised that the measurement of H was difficult with a 30 cm ruler and so the absolute uncertainty in their value was greater than the precision of the ruler scale.

(c) Candidates were asked to determine the period of the oscillations of the wooden strip. Many carried this out competently, showing their working for each stage of the procedure. Other weaker candidates appeared to have little experience of the process and several types of error were seen. In some cases the period was taken to be the time for half an oscillation or as the time for several oscillations, and in others there was no evidence of repeated measurements with averaging.

(d) Most candidates repeated the tests using a smaller length *L* for the curved ruler and most found that the value of *T* was increased, as expected.

(e) (i) Most candidates correctly calculated two values for the constant *k*, with just a few making an error in rearranging the expression provided. Although not specifically asked for, the strongest candidates included a unit with their values, and this proved useful later in the question.

(ii) When asked to justify the number of significant figures they had given for *k*, only a small number of candidates mentioned every measurement involved in the calculation. Candidates should avoid vague references such as 'raw data' and ensure they list all the quantities that are involved.

(iii) The evaluation of the suggested relationship was carried out very well by many candidates. They looked at the variation between the two *k* 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 *H* earlier in the question).

(f) Most candidates carried out the numerical calculation of *g* correctly but there were some mistakes with the unit and the power of ten. Those candidates who had previously included a unit for their *k* value often then found it easier to decide whether to use the strip length *S* in cm or m.

(g) In this experiment candidates were asked to bend a 30 cm ruler to a specified length and then fix it in this shape using adhesive tape. This manipulation was not easy and candidates who described some of the difficulties were awarded credit. Many stronger candidates went on to suggest a workable alternative to using tape, such as trapping the bent ruler between blocks clamped to the bench. This arrangement was also accepted when described as an improved method of measuring the bent length *L*.

Many candidates identified the difficulty of judging the start and end of oscillations when determining *T*. Of these, many suggested using a video recording (with a timer included in the view) which could be viewed as it was replayed slowly. The improvement of using a fiducial marker at one end of the oscillating strip was also accepted as long as its position was stated to be at the centre of the motion. Some candidates suggested that there was a large percentage uncertainty in *T* because its value was small. This was not accepted as the uncertainty could easily be reduced by measuring the time for several oscillations.

The measurement of the height *H* of the bent ruler using another ruler also presented problems. Candidates who described a valid difficulty and linked it to *H* were awarded credit, with many identifying parallax error or the need to deal with the unused part of the measuring ruler at the end of its scale. Several valid improvements were suggested by candidates, usually involving an alternative measuring instrument or technique.

PHYSICS

Paper 9702/41
A Level Structured Questions

There were too few candidates for a meaningful report to be produced.

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 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 that 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 use of correct physics, it is often possible for examiners to award partial credit even when the final answer is incorrect. Incorrect answers that are not supported by working cannot be awarded credit.

- Answers to numerical questions should be given to an appropriate number of significant figures; the precision of the data provided in the question is generally indicative of the appropriate number of significant figures for an answer. When performing intermediate calculations within a question, candidates should take care to avoid premature rounding; as a general rule, any intermediate calculated values should always carry at least one more significant figure than will be used in the final answer. Candidates should be made aware that giving answers to an inappropriate number of significant figures, or that are inaccurate as a result of rounding intermediate values prematurely, can both lead to full credit not being awarded.

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 who were properly prepared for the examination 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 award partial credit.

Some candidates did not express numerical values with significant zeros correctly (e.g. giving '2' when the correct answer is '2.0'). Candidates should be reminded that significant zeros are no less significant than any other significant digits.

Comments on specific questions

Question 1

(a) Many candidates were able to recall that gravitational potential involves work done in moving mass from infinity. Fewer correctly identified it correctly as a work done per unit mass. Many responses given by candidates defined a quantity that was dimensionally equivalent to an energy.

(b) (i) Candidates who knew (or were able to deduce from the equation for gravitational potential) the equation for the gravitational potential energy between point masses were usually able to achieve at least partial credit in this question. Common mistakes in the substitution were either to only consider the potential energy at a single point or to take the distance between the masses at the second point as the height above the Earth's surface. Candidates who substituted correctly were usually able to calculate the correct final answer, although some candidates gave an answer to only one significant figure.

(ii) A common incorrect starting point for this question was to equate the answer to **(b)(i)** with the kinetic energy of the satellite. Many of the candidates who did use the correct physics as their starting point (equating the expressions for gravitational and centripetal force) were able to calculate the correct answer. Some candidates used the mass of the satellite (rather than the mass of the Earth) when substituting into $v^2 = GM/r$.

(c) Many candidates presumed that this question was something to do with geostationary orbits and that the orbit of the satellite had to be geostationary. Some candidates confused the meanings of 'orbit', 'rotation' and 'movement' when describing the Earth, or gave an incorrect direction of rotation of the Earth. There were also some very good answers given by candidates, and the mark scheme allowed a wide variety of possible answers.

Question 2

(a) Many candidates attempted to give a description of the first law of thermodynamics rather than a definition of internal energy. Those who discussed the sum of kinetic and potential energies often incorrectly stated that these energies were of the system rather than of the particles in the system. For full credit, there needed to be some reference to random movement (or random distribution) of the particles. Some candidates gave answers that suggested they were not sure exactly what was random, e.g. 'the random sum (of energies)' or 'random systems'.

(b) (i) This question was generally well answered, with many candidates achieving full credit. Some candidates gave their final answer to only one significant figure.

(ii) This question was also generally well answered, this time with most candidates giving the correct answer to the required precision.

(c) (i) Most candidates were able to substitute correctly the values given in the question into $W = p\Delta V$ to get the numerical value of 390 J. A smaller number correctly gave a negative answer for the work done on the gas and explained why this value is negative for full credit.

(ii) Most candidates could use the first law of thermodynamics to add their answer to **(c)(i)** to 980 J to find the change in internal energy of the gas.

Question 3

(a) The two defining characteristic properties of simple harmonic motion were generally well known, although some candidates found it difficult to articulate the fact that acceleration and displacement are always in opposite directions to each other.

(b) (i) Most candidates realised that the kinetic energy of the sphere at its maximum displacement is zero. Some attempted a calculation. It is worth reminding candidates that questions with the command word 'state' may answered without calculation.

(ii) This question required candidates to appreciate that the total energy of the oscillations is equal to the potential energy of the sphere at its maximum displacement. Those candidates who did realise this were usually able to achieve credit, although with a small number making either one or two power-of-ten errors in the unit conversions for the height and the mass. A significant proportion of candidates saw the phrase 'total energy', and then attempted to use the equation $E_T = \frac{1}{2} m\omega^2 x_0^2$ without appreciating that they did not have enough information for this equation to be useful at this stage.

(iii) Candidates who realised that this was the point to introduce the 'total energy' equation were generally able to show that ω has the stated value. A large number of candidates invented a value (of 1.90 s) for the period of the oscillations and used it to 'show' the value of ω; this approach could not be awarded credit.

(c) Most candidates were able to use the given value of ω to determine a value for the period and then substitute this (together with the value of *g*) into the given equation. Some found it difficult to rearrange the equation correctly in order to determine a value for *L*, but most did calculate a value for *L*. Some candidates gave the final answer to an insufficient number of significant figures.

Question 4

(a) Some weaker candidates attempted to answer a different question here from the one that was asked. Responses concerning attenuation, bandwidth, crosstalk and interference were common.

For candidates who did address the advantages of digital transmission over analogue transmission, there was some confusion relating to noise. A common misunderstanding is that there is no noise in digital transmission (or that, somehow, there is less of it). To be awarded credit, candidates need to appreciate that there is noise, but that it can be easily dealt with by the regeneration amplification process. Another common misconception is that digital signals travel faster, or that more data can be transmitted. Candidates who stated that data can be transmitted at a greater rate were awarded credit.

(b) (i) Some candidates underlined a digit in the wrong cell or gave contradictory responses by underlining more than one digit. Weaker candidates often did not attempt the question. In general, the stronger candidates answered this question correctly.

(ii) Common mistakes were to give the analogue values to insufficient precision and to give the binary value at 0.40 ms as 0101. However, most candidates were able to access at least partial credit here, and many achieved full credit.

(c) Most candidates found this question difficult, and freehand attempts at simply trying to reproduce the graph of Fig. 4.2 were common. Some candidates did realise that the output is stepped at 0.10 ms intervals, but did not appreciate that the precision of the digital signals rounded the output down to the nearest millivolt at the sample times. Other candidates did appreciate the rounding of the values at the sample times but did not appreciate the stepped nature of the output.

Question 5

(a) (i) Most candidates realised that a field is a region in space where a force acts, but a significant minority were not able to describe on what the force acts. Some candidates described a specific type of field as opposed to a field in general.

(ii) No credit was given for repeating either information given in the question or the meaning of a field already answered in **(a)(i)**. The differences between the two types of field were slightly better understood than the similarities, although there were some responses that addressed the issue of 'direction' where the directions specified were unclear (discussion of 'positive' and 'negative' directions being the most common example of this). Some otherwise correct similarities were contradicted, and a common example of this was responses stating that the fields are both radial and parallel.

(b) (i) This question was generally well answered, and most candidates who knew the equation for the electric field due to a point charge calculated the value of *Q* correctly.

(ii) Candidates who answered **(b)(i)** correctly usually answered **(b)(ii)** correctly as well. Candidates who used incorrect physics in answering **(b)(i)** usually used the same misconceptions in answering **(b)(ii)**. The most common incorrect physics was to take electric field strength to be inversely proportional to distance rather than to distance squared.

(c) Many responses neglected the region from $x = 0$ to $x = 0.15\,\text{m}$. Of those who did address this region, it was common for candidates to be unaware that the electric field strength inside the sphere must be zero. Curves outside the sphere showing an inverse square relationship passing through the correct points were more common. The curves were sometimes spoilt by being straight for too much of their length, by starting vertically or by ending horizontally.

Question 6

(a) (i) The majority of the candidates successfully defined capacitance in general as charge per unit potential. Fewer candidates were able to correctly define what is meant by ‘charge’ and ‘potential’ in the context of a parallel plate capacitor.

(ii) Most candidates were able to achieve at least some credit on this question, and many achieved full credit. At least some of the functions were generally well known. Candidates need to be careful to make it clear that the role of capacitors in the rectification and smoothing process is smoothing, not rectification.

(b) Both parts of this question were generally well answered. Common mistakes were the use of an incorrect symbol for the capacitor, giving the two responses the wrong way around, and using more than the three capacitors specified in the question.

Question 7

(a) A very common misconception held by candidates was that the electrons arriving at the target anode had a range of different kinetic energies. This is not the case because they are all accelerated through the same potential difference between the cathode and the anode. Another common confusion was with the photoelectric effect (and some need for electrons to reach the surface before being emitted being responsible for the range of wavelengths). The fact that it is the deceleration of the electrons (at the anode) that is responsible for production of X-ray photons was not well understood.

(b) Many candidates incorrectly attributed the spikes in the X-ray spectrum to pulses of intensities in the electrons arriving at the anode. Only the strongest candidates realised that the spikes are due to excitation and de-excitation of electrons in the target atoms. Few candidates made the link between the wavelengths of the spikes and the photon energies corresponding to the differences in the discrete energy levels of the electrons in the target atoms.

Question 8

(a) (i) The meaning of infinite bandwidth was not well understood by many candidates. Others had an idea that something is the same for all frequencies, but were unable to articulate clearly enough what is the same because they did not know or use the word ‘gain’.

(ii) This question was answered more successfully than **(a)(i)**. Candidates needed to include in their response the idea that there is no time delay between changes in the input signal and consequent changes in the output signal.

(b) (i) This question was generally well answered by candidates who knew the definition of gain.

(ii) A common mistake was to think that the circuit represented an inverting amplifier. Candidates who realised that the circuit is a non-inverting amplifier, and who knew the equation for the gain of a non-inverting amplifier in terms of the resistances in the circuit, were generally able to calculate the correct answer.

Question 9

(a) (i) Most candidates realised that Faraday’s law relates to the magnitude of the induced e.m.f., and most of those who did realise this were then able to go on to give a correct statement of the law.

(ii) The question follows on directly from the relationship between induced e.m.f. and rate of change of magnetic flux represented by Faraday's law in **(a)(i)**. Candidates were expected to realise that Fig. 9.2 shows that the magnetic flux in the solenoid is only changing for very short periods of time near t_1 and t_2, and is otherwise constant. Many candidates correctly showed that the e.m.f.s induced at t_1 and t_2 have opposite polarities.

(b) This question required candidates to appreciate that the magnitude of the Hall voltage is directly proportional to the flux density of the magnetic field it is measuring. Of candidates that did realise this, many were able to achieve credit for the correct general shape of the graph. Fewer candidates were able to give the correct durations of the changes at t_1 and t_2.

Question 10

(a) Many candidates seemed to know the field pattern but were unable to achieve full credit because their drawing was not sufficiently careful. Most were able to gain credit for drawing concentric circles and many realised that the direction of the field was anti-clockwise. Many candidates did not show increasing separation of the circles sufficiently clearly. Candidates who used a compass to draw their circles found it easier to access this mark than those who tried to draw their circles freehand.

(b) (i) Many candidates attempted to answer a different question from the one that was asked. Responses discussing the magnitudes and/or directions of the forces were common. This question asked candidates to explain why the forces are exerted. It was not possible to answer the question without discussion of the currents in the two wires.

(ii) Many answers were either incorrect or too vague to be able to be awarded credit (e.g. 'opposite directions', 'left and right'). The most succinct answer was to state that the forces between the wires are attractive, but it was also possible to achieve credit by discussing the directions on the forces on the two wires separately, provided that the descriptions were correct for both wires.

(c) A high proportion of candidates stated that the magnitudes of the forces are different because the currents in the wires are different. Most of the candidates who responded correctly gave explanations in terms of Newton's third law. Correct explanations in terms of the force depending on the product of both currents were also seen.

Question 11

(a) There were many responses that attempted to reproduce 'standard answers' learnt from previous mark schemes here, as opposed to addressing the question that was asked. This particular question gave the existence of a threshold frequency as one of the pieces of evidence from the photoelectric effect for the particulate nature of electromagnetic radiation, and asked for two others. Candidates giving points concerning threshold frequencies/wavelengths could not be awarded credit as this repeated information already provided in the question. Many other responses were seen that were not observations from the photoelectric effect but rather explanations of it.

For candidates who did give responses that answered the question, there was often confusion between photons and electrons (with some candidates discussing the frequency of incident electrons, and others discussing the speed of emitted photons).

(b) (i) Many candidates did not appreciate the need to extrapolate the line to read off the value of $1/\lambda$ at $E_{MAX} = 0$. Some candidates either made a power-of-ten error in the read-off, or then treated the read-off as a value of λ when going on to use the equation relating threshold frequency and threshold wavelength. Only the strongest candidates correctly calculated the threshold frequency.

(ii) Most candidates determined the gradient of the line in Fig. 11.1. The analysis of the photoelectric effect equation leading to a demonstration that the gradient represents hc was often not well shown.

(c) Most candidates were able to achieve at least partial credit here, and in general the responses showed a good attention to detail.

Question 12

(a) (i) Candidates who knew the basic 'bookwork' were usually able to achieve at least partial credit for this definition. In answering question like this, it is essential that candidates use terms like nucleons and nucleus correctly.

(ii) Many candidates demonstrated confusion between nuclear fission, nuclear fusion and radioactive decay. In discussing a large nucleus splitting into two smaller nuclei, it is helpful for candidates to use the singular and plural of the word 'nucleus' correctly. Candidates were awarded credit where it was clear in context whether the candidate meant singular or plural, but this is not possible if use of the incorrect term causes ambiguity in what the candidate is trying to describe.

(b) Candidates found this question difficult, and a large proportion of candidates demonstrated a fundamental confusion between the concepts of nuclide mass and nucleon number. These candidates incorrectly thought that, for energy to be released in a reaction, there has to be a change in nucleon number. A common answer was that there is no change in nucleon number and therefore no energy released.

Those candidates who started by considering the variation with nucleon number of binding energy per nucleon were usually able to achieve partial credit, but only the very strongest candidates were able to give a complete answer and achieve full credit.

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 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 that 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 use of correct physics, it is often possible for examiners to award partial credit even when the final answer is incorrect. Incorrect answers that are not supported by working cannot be awarded credit.

- Answers to numerical questions should be given to an appropriate number of significant figures; the precision of the data provided in the question is generally indicative of the appropriate number of significant figures for an answer. When performing intermediate calculations within a question, candidates should take care to avoid premature rounding; as a general rule, any intermediate calculated values should always carry at least one more significant figure than will be used in the final answer. Candidates should be made aware that giving answers to an inappropriate number of significant figures, or that are inaccurate as a result of rounding intermediate values prematurely, can both lead to full credit not being awarded.

General comments

It was relatively common to see answers to a different question from the one asked, particularly in **Question 4** on ultrasound. Candidates should be discouraged from memorising previous mark schemes and applying them to new questions.

Knowledge of the formula sheet is important. Candidates should be familiar with the equations that are provided as well as with the meaning of all the symbols in these equations. It was clear in **8(c)** that many candidates did not realise that the formula for the Hall voltage was provided for them.

Comments on specific questions

Question 1

(a) (i) Many responses gained full credit. Some candidates referred to the force due to the field only acting on a mass. This question asked for a general explanation of what is meant by a field of force and so a general answer was expected.

(ii) This question was well answered.

(b) The majority of candidates knew the correct formula to use to calculate the gravitational field strength at the surface of the planet. As the data were provided to three significant figures, an answer was expected to three significant figures.

(c) A small number of candidates calculated the height for a gravitational field strength of 1.0%, rather than a 1.0% reduction in the gravitational field strength. A significant number of candidates found the radius from the centre of the planet to the required position, but then did not subtract the radius of the planet in order to find the height above its surface.

Question 2

(a) Many candidates correctly stated the meaning of the terms from the first law of thermodynamics. It is important that the directions of thermal energy transfer and work done relative to the system are clear.

(b) (i) Most candidates were able to show how to do this calculation of work done to the required level of detail.

(ii) Many candidates stated that there was no change in internal energy after a whole cycle of changes. However, only stronger candidates were able to explain that this was because the initial and final temperatures were the same.

(c) Completing this table proved to be challenging. Candidates had difficulty in relating the numbers they already knew to this table for the whole cycle of changes.

Question 3

(a) Many responses gained full credit here.

(b) Some candidates correctly used the graph to find the frequency of the oscillations. A common mistake was to try to use $v_0 = x_0\omega$ by substituting in any coordinate from the ellipse, rather than v_0 and x_0. This equation relates only the maximum speed and amplitude and cannot be used with an arbitrary pair of velocity and displacement values.

(c) Most candidates were able to use the provided equation and calculate the length of the pendulum. Candidates are encouraged to check their work when an answer seems unlikely, for example a pendulum of 276 m or 8.4×10^{-3} m in length.

(d) A large number of candidates worked out how a new pendulum with the same amplitude but a longer length would change the shape of the graph. Some candidates incorrectly showed the amplitude increasing or decreasing with no change to the maximum velocity.

Question 4

(a) Many candidates were able to fully explain the principles of generation of ultrasound waves. Some did not realise that the piezoelectric crystal only vibrates when an alternating p.d. is applied. Other responses did not explain the generation of ultrasound but instead attempted to explain the formation of an image.

(b) Candidates often stopped after finding the ratio of intensities and did not go on to convert this ratio into dB. For those who did, only a small proportion evaluated the ratio correctly to include the negative sign with their answer. Some candidates made the calculation more challenging by converting cm into m and attempting to convert cm^{-1} to m^{-1}, and this often led to errors. These conversions were not necessary.

Question 5

(a) In a definition of this type, where there is the division of two quantities, candidates need to use the phrase 'per unit' to make this division clear. Stating that it is the work done to move a charge does not indicate that the work is divided by the charge.

(b) (i) Candidates found determining this charge very challenging. Many used any point on the curve and the formula for electric potential of a point charge. Only a small number of candidates realised that the point where the electric potential is zero was the correct one to use. Some candidates incorrectly used the formula for electric field strength rather than the one for electric potential. Others did not realise that the charge of B is negative.

(ii) There were a significant number of errors with the powers of ten. Another common error was not correctly finding the difference between the positive potential at 3.0 cm and the negative potential at 9.0 cm.

(c) Candidates who knew the two formulae to equate here for conservation of energy generally answered successfully, although there were some errors made with the mass of the α-particle and the charge of the α-particle. Weaker candidates often did not know where to begin and often equated kinetic energy with potential difference rather than work done.

Question 6

(a) (i) Most candidates gained credit for the correct ratio. Fewer gained full credit for the detail required about the charge and the p.d. when related specifically to a parallel plate capacitor. A small number of candidates were confused by the phrase 'parallel plate capacitor' and gave the formula for the combined capacitance of capacitors connected in parallel.

(ii) There were many correct answers here.

(b) Many candidates worked through this calculation very easily. Some candidates swapped the use of the formulae, using the parallel formula for the capacitors connected in series and vice versa. Some candidates could not visualise the network and had two series pairs connected in parallel, or all four connected in series.

Question 7

(a) There was large variation in how this circuit diagram was completed. Weaker candidates often did not know the basic arrangement of two potential dividers. Stronger candidates usually knew the arrangement but often could not position the thermistor correctly. Some candidates did not gain full credit because they did not use correct circuit symbols.

(b) There were many correct answers here. A significant number of responses had the two values reversed and some weaker candidates offered temperatures instead of resistance values.

Question 8

(a) (i) The most common error was to give the opposite direction to the correct answer, because of confusion between current and direction of movement of electrons.

(ii) There was a large number of correct responses here, but candidates needed to look at the diagram carefully. Some responses confused M and Q.

(b) This description was challenging. Candidates rarely referred to an electric field being created (due to the movement of the electrons) or to the forces due to the electric and magnetic field being both equal in size and opposite in direction.

(c) There were many correct answers, but weaker candidates often did not realise that the formula they needed was given at the front of the paper. Some candidates attempted to multiply the number of free electrons per unit volume by the volume of the slice due to misunderstanding the meaning of *n* in the formula.

(d) Often candidates knew that *n* was (much) smaller for semiconductors and how this would affect the potential difference across the slice. Only the stronger candidates could relate this to a measurement being possible/easier, measurements being the purpose of a Hall probe.

Question 9

(a) This was relatively well known as a definition, but a significant number of candidates confused the definition with flux density or flux linkage.

(b) (i) Candidates found this description challenging. The key ideas needed here were that the flux was changing and caused by the current, the flux was linked to the secondary by the core and the changing flux induced an e.m.f. The fact that the flux was changing was not often mentioned and the core was rarely part of the description.

(ii) Again, this explanation was challenging. Candidates often did not realise that the key concept here is the rate of change of flux, as per Faraday's law.

(c) Responses often referred to eddy currents but did not mention that they are in the core. The fact that these eddy currents are reduced by the laminations which then reduced the heat losses was often omitted.

Question 10

(a) Some candidates could explain the principles of computed tomography very well. However, there was much confusion between 'images'/'scans' and 'slices'/'sections'. Another detail that was often missing was that the final product of the scan is a three dimensional image of the whole structure or body.

(b) Many candidates gained full credit here. However, the order of the letters relative to the boxes needed to be carefully observed.

Question 11

(a) (i) Many candidates gained full credit here. A common error was to omit the word 'energy' which is fundamental when explaining the nature of a photon.

(ii) Most candidates were able to draw the correct direction for the motion of the deflected electron.

(b) (i) This calculation was completed well by those who knew the correct formula. An answer to three significant figures was expected as the data were to three significant figures.

(ii) This calculation was more challenging than that in **(b)(i)**. The most common error was in not calculating the energy of the photon before and after deflection but instead attempting to use a change in wavelength as the denominator in an energy calculation.

(c) This is a difficult concept to describe and the question was well answered in general.

Question 12

(a) (i) Radioactivity is a nuclear process and as such, all answers should refer to the nucleus. Candidates should be careful to use correct terminology, for example 'nucleus' rather than 'atom'. Some responses confused radioactive decay with fission and fusion.

(ii) Many candidates gained full credit. Again, it is important to use precise terminology: the probability of decay of 'a substance' is incorrect. The use of the word 'per' is vital in order to describe the ratio with time here.

(b) This calculation was generally answered very well.

(c) This calculation was completed well. The most common incorrect approach was to attempt to calculate a value for the decay constant when this value had already been given earlier in the question.

PHYSICS

Paper 9702/51
Planning, Analysis and Evaluation

There were too few candidates for a meaningful report to be produced.

PHYSICS

Paper 9702/52
Planning, Analysis and Evaluation

Key messages

- 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. A full understanding of significant figures and the treatment of uncertainties is required.
- 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. Planning a few key points before answering **Question 1** is useful. When quantities are given designated symbols in the question, candidates should make use of these symbols. When candidates introduce symbols that they do not define, it is difficult to be certain exactly which quantity is being discussed. In this question, the strongest candidates were specific when discussing the mass *m* or mass *P*.

Successful candidates make specific statements rather than vague generalities, for example 'use a stop-watch to measure the time for the trolley to move a distance *d*', rather than 'measure time with a stop-watch', 'measure distance *d* with a rule' rather than 'measure distance with a rule', and 'for each value of *m* repeat the reading of *t* and take the average' rather than 'repeat and average the readings'.

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 uncertainties, 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 later parts of the question requires a clear statement of the equation used with correct substitution of numbers, and the answer calculated including the correct power of ten. Candidates should set out their working in a logical and readable manner. Care should be taken when numbers are crossed out.

Comments on specific questions

Question 1

Most candidates correctly identified the independent and dependent variables. When considering the control of variables, some candidates were confused between which values are constant (Q, R and g in this case) and which are variable quantities that need to be *kept* constant (the distance d and mass P). Some candidates used the incorrect term 'control' rather than stating that d and P needed to be kept constant. Candidates should identify the variables to be controlled from the given relationship.

Candidates were awarded credit for a clearly labelled diagram. Diagrams should be drawn of the workable setup of the experiment. Items such as balances, stop-watches etc. do not need to be shown unless their specific placement is essential to the working of the experiment. In this experiment, candidates needed to clearly show the surface, trolley and mass m, together with a string connected horizontally to the trolley at one end and vertically to a labelled mass P at the other end. The string needed to pass over a supported pulley and the pulley needed to be labelled.

Most candidates gained credit for suggesting using a rule to measure the distance d, a balance to measure the mass m, and the measurement of an appropriate distance and time to enable the final velocity to be calculated. Stronger candidates suggested repeating the measurements and finding the mean of the time or velocity for each value of m. Most candidates chose to find velocity by measuring the time t taken for the trolley to move the distance d. Credit was not given to candidates who divided d by t to give the average velocity of the trolley rather than the required final velocity. A few candidates doubled the average velocity to correctly calculate the final velocity. Some candidates calculated the final velocity more directly by finding the time taken for a narrow card on the trolley to pass through a light gate which was fixed at the end of the run and connected to a timer. It is generally expected that standard laboratory apparatus will be used, so using apparatus such as a 'speedometer' was not acceptable without valid further explanation.

Some candidates gained credit for stating that a larger value of d would make their results more accurate, and a few also for stating that a spirit level should be used to check that the wooden surface was horizontal. The word 'level' is an acceptable alternative to 'horizontal', but some candidates used the word 'flat', which was not credited because a board could be angled to the horizontal but still be a flat surface.

Candidates should consider the safety aspects of their experiment. There are times when using safety equipment such as goggles or safety shoes can be justified as good practice, but the emphasis should be on making the experiment safe rather than providing protection from the dangers of an unsafe experiment. In this case credit was given for methods of preventing the mass m from falling from the trolley, preventing the trolley from falling from the wooden surface, or preventing the falling mass P from damaging the floor or bouncing out of control.

Several candidates mentioned the use of video recording as a means of timing the motion. In general, this is only valid if the recording includes an image of a timer. Any use of slow-motion playback or frame-by-frame analysis needs further detail of how the time will be determined.

Many candidates successfully rearranged the equation given into a form equivalent to $y = mx + c$, and used this to successfully determine the graph to be plotted. Only axes of $1/v^2$ and m were workable for the equation being tested, and candidates who either guessed or wrongly interpreted the equation to plot values of v^2 and $1/m$ did not gain credit. 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, or for saying to 'plot a graph of the equation'.

Having suggested an appropriate graph, candidates needed to explain the conditions needed for the graph to confirm the suggested relationship. Candidates should use the words 'relationship is valid if' and the word 'straight' to describe the line. Candidates needed to explain how they would determine values of Q and R from their results, and many explained this clearly. Some candidates correctly identified a relationship between Q and the gradient and between R and the y-intercept, but did not make Q and R the subject of their equations.

Candidates should be encouraged to write their plans including appropriate detail. 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.

Question 2

(a) Most candidates were able to write down the answer directly.

(b) Most candidates gave correct values of 1 / *d* to 2 or 3 significant figures. A common error was to round 0.667 to 0.66. Some candidates gave their answer to an unjustifiable 1 significant figure. A significant minority of candidates recorded all the uncertainties as 0.1 and did not gain credit.

(c) (i) The points and error bars were straightforward to plot. Some candidates drew large blobs for the plotted points which could not be awarded credit. Points should be as sharply defined as possible – the diameter of each point should be less than half a small square. Error bars were usually accurate and symmetrical, but some candidates drew them in the *y* direction instead of the *x* direction.

(ii) Most candidates appear to be using a sharp pencil and a transparent 30 cm ruler which covers all of the points. The line of best fit should be the best line taking account of all of the points plotted. The worst acceptable line was drawn well in general, but some candidates were not sufficiently careful to draw their lines accurately at the ends of the error bars. Candidates should clearly indicate which of the lines drawn is the line of best fit and which is the worst acceptable line. 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 sensibly sized triangle. A small number of candidates chose data points that did not lie on the lines, often using data from the table that is close to the line instead. Candidates should be encouraged to select two points which are easy to read from the graph.

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. In calculating the absolute uncertainty in the gradient, there must be evidence of subtraction between the gradient of the line of best fit and the gradient of the worst acceptable line. A small minority of candidates attempted to find the uncertainty in the gradient from the uncertainty value of one of the data points, which is not a valid method and did not gain credit.

(d) (i) Most candidates obtained the correct numerical value, but many candidates were confused by the units and had power-of-ten errors. Many candidates gave their answers to too many significant figures, and some to too few.

(ii) Stronger candidates clearly demonstrated how to calculate uncertainties for subtracted and divided quantities. The most common error was not to realise that the calculated mass value of 184 g had an uncertainty of ± 2 g. Some candidates correctly calculated the uncertainty as 2.46%, then rounded it up to 2.5%, then later gave their answer as 3%.

(e) Candidates needed to show clear and logical working for this question. Clear substitution of numbers into equations was needed to determine σ and to determine the absolute uncertainty. Most candidates found a value for σ but powers of ten caused some confusion.

Many candidates successfully worked out the correct unit, although weaker candidates often made no attempt to do so. Some candidates did not realise that mm and m are the same dimensionally, and stated units containing the same dimension multiple times (e.g. $kg\,mm^{-2}\,m^{2}\,s^{-2}$). This was not credited as a valid unit.

Most candidates who calculated the uncertainty did so by adding the uncertainties in the gradient and the density. Of those who used a maximum/minimum method, most used a correct worst gradient value but not the corresponding worst density value. Some candidates were not awarded credit because they did not show their working or substitution of numbers.

(f) Stronger candidates answered this question well. The most common errors were power-of-ten errors. A large proportion of candidates did not give a unit for their answer.

PHYSICS

Paper 9702/53
Planning, Analysis and Evaluation

Key messages

- 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. A full understanding of significant figures and the treatment of uncertainties is required.
- 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. It is vital that candidates understand and plan how the experiment is to be conducted.

There were some unworkable setups shown in diagrams. Many diagrams had apparatus drawn in 'mid-air'. Drawing a horizontal line representing a bench top with apparatus placed on it is a good starting point. For accurate measurements, vertical rulers should be clamped.

Many candidates did well in the analysis part of **Question 1** with clear identification of how the constants could be determined.

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 uncertainties, 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 later parts of the question requires a clear statement of the equation used with correct substitution of numbers, and the answer calculated including the correct power of ten. Candidates should set out their working in a logical and readable manner. Care should be taken when numbers are crossed out.

Comments on specific questions

Question 1

The majority 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. In this experiment, the mass of the load *m* needed to be kept constant; the word 'mass' on its own did not gain credit since it could be taken as the mass of the spring. A small number of candidates used the incorrect term 'control' rather than the correct term 'constant'.

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 clearly show a spring with one end attached to a support and the other end attached to the labelled load. Credit was also given for showing a clamped vertical ruler positioned close to the spring.

Many candidates were aware of the need to use a set square to check the vertical position of the ruler used in the experiment. Further credit was available for the diagram showing a clamped ruler with the set square touching the ruler and a bench. A few candidates cited a fiducial marker drawn correctly in the diagram and gave a correct explanation of its use.

Most candidates gained credit for suggesting using calipers or a micrometer screw gauge to measure the diameter of the metal wire. Further credit was available for an explanation of how to determine the cross-sectional area of the wire. Some candidates confused the diameter of the wire (and cross-sectional area of the wire) with the width *w* of the spring.

The majority of candidates explicitly stated the correct quantities to be plotted on each axis of a graph. There were a number of logarithmic combinations. Weaker candidates either did not specify the axes or suggested plotting *x* against *A*. Having suggested an appropriate graph, candidates needed to explain how the graph would confirm the suggested relationship. Candidates must be careful in their description using the phrase 'relationship is valid if'. The word 'straight' is required to describe the line. The use of logarithms and subsequent manipulation of the formula to find γ was generally well done. Some candidates did not gain credit because they omitted *N* in the final expression.

Candidates should be encouraged to write their plans including appropriate detail. 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.

Many candidates were able to cite the density equation but did not define the mass and volume in terms of the experiment. Candidates generally realised that repeat readings were desirable but did not give sufficient detail. Credit was given for detailed explanations, e.g. repeat the measurement of *w* in different directions and average.

Question 2

(a) Many candidates were able to work through the algebra to achieve credit.

(b) The majority of candidates were able to complete the table correctly. A common error was not giving the value of h_i / h_o to the correct number of significant figures. Since both h_i and h_o were given to two significant figures, it was expected that h_i / h_o would be given to two or three significant figures.

(c) (i) The points and error bars were straightforward to plot. Candidates generally plotted their points with care and accuracy. The diameter of each point should be less than half a small square.

(ii) Candidates who are successful appear to be using a sharp pencil and a transparent 30 cm ruler which covers all of the points. The line of best fit should be the best line taking account of all of the points; sometimes the line drawn did not reflect the balance of points about it.

In general, the worst acceptable line was drawn well, and most stronger candidates drew a line that 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. Candidates should be encouraged to read the quantities from the axes carefully.

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. In calculating the absolute uncertainty in the gradient, there must be evidence of subtraction between the gradient of the line of best fit and the gradient of the worst acceptable line.

(iv) The majority of the candidates who were awarded full credit set out their working clearly. Many candidates correctly substituted a data point from the gradient calculation of the line of best fit into $y = mx + c$.

When determining the y-intercept of the worst acceptable line, candidates need to clearly show the substitution into $y = mx + c$ of a point from the worst acceptable line and the gradient of the worst acceptable line from **(c)(iii)**. Subtraction is then required to obtain the uncertainty.

Since the graph had a false origin, a common mistake was incorrectly reading the y-intercept directly from the y-axis.

(d) (i) Candidates must clearly show how the gradient, the y-intercept and the equations from **(a)** were used. Most candidates were able to determine f, although many candidates did not give the correct unit. The majority of the candidates gave an appropriate number of significant figures. Stronger candidates stated a correct equation followed by clear working to obtain the absolute uncertainty in f.

(ii) To gain credit, clear and logical working with numerical substitutions into the correct equation for t needed to be seen. Stronger candidates clearly presented their working in a readable, logical order. When crossing out work, candidates must make it clear where the corrected work fits into the logical sequence of the calculation.