PHYSICS

Paper 9702/11
Multiple Choice

Question Number	Key
1	C
2	B
3	D
4	B
5	C
6	C
7	C
8	A
9	A
10	D

Question Number	Key
11	D
12	A
13	C
14	A
15	C
16	B
17	B
18	A
19	A
20	D

Question Number	Key
21	A
22	C
23	C
24	C
25	B
26	A
27	C
28	D
29	A
30	C

Question Number	Key
31	B
32	D
33	B
34	C
35	A
36	B
37	D
38	D
39	D
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 need to make sure 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.

Candidates found **Questions 10, 20, 22, 24 and 25** particularly difficult, but found **Questions 1, 3, 5, 14, 17, 19, 31 and 38** relatively straightforward.

Comments on specific questions

Question 2

Candidates who were incorrect frequently made a power-of-ten error when converting cm^3 into m^3. Candidates are expected to recall that the diameter of an atom is of the order of 1.0×10^{-10} m; a reasonable estimate of the volume of an atom is then 1.0×10^{-30} m^3. The number of atoms in a piece of metal of volume 50 cm^3 is then:

$$\frac{50 \times 10^{-6}}{1.0 \times 10^{-30}} = 5.0 \times 10^{25} \text{ (answer } \mathbf{B}\text{).}$$

Question 6

Candidates mostly answered this question correctly. Candidates who were incorrect frequently used 12 $m s^{-1}$ as the vertical component of the velocity of the ball rather than $12 \sin 50°$ $m s^{-1}$.

Question 7

Less than half the candidates answered this question correctly, with many candidates omitting '*g*' from their calculation and/or ignoring the fact that the drone has four propellers.

Question 8

Candidates found this question challenging, with many selecting force **B** rather than the correct force **A**. As the box is at rest, the weight of the box is equal to force **B** but this is not the other force in the pair with the weight *W* of the box. Two key points should be recalled when applying Newton's third law:

- the two forces act on **different objects**;
- the two forces are of the **same type**.

In this example, the two objects are the box and the Earth; the two forces are both gravitational.

Question 9

Most candidates recognised that the drag force is zero when the ball is stationary but candidates also needed to recall that the greater the speed of the ball, the greater the viscous (drag) force (answer **A**).

Question 10

Candidates found this question very challenging. To find the correct answer, the principle of conservation of linear momentum must be applied carefully, noting that the mass *m* **rebounds** along its original path. It is also important to realise that if the mass *m* has $\frac{1}{4}$ of its original kinetic energy after the collision, it must have half the speed, since kinetic energy is proportional to the square of the velocity.

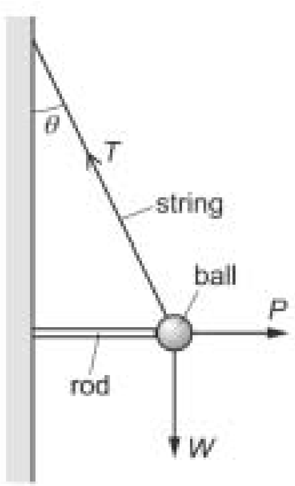
Applying the principle of conservation of linear momentum:

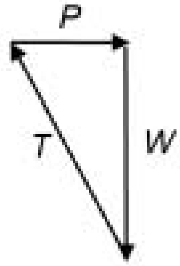
$$4mv - m\frac{u}{2} = mu \quad v = \frac{3u}{8} \text{ (Answer } \mathbf{D}\text{).}$$

Question 13

Some candidates who answered incorrectly confused $\cos\theta$ and $\sin\theta$ when calculating the horizontal and vertical components of T (answer **A**).

One approach is to draw the force triangle for the forces acting on the ball:





By Pythagoras' theorem: $T^2 = P^2 + W^2$ (answer **C**)

Question 15

Many candidates selected answer **B** (the percentage of the volume of the ball **below** the surface of the water) instead of the correct answer **C**.
Let the volume of the ball **below** the surface of the water be V. From Archimedes' principle:

$$1.0 \times 10^3\ Vg = 0.50g$$
$$V = 5 \times 10^{-4}\ \text{m}^3$$

The percentage of the ball below the surface is $\dfrac{5\times10^{-4}}{1.3\times10^{-3}} \times 100 = 38\%$ (answer **B**)

The percentage of the ball **above** the surface is 100 – 38 = 62% (answer **C**)

Question 18

If the weight of the lamp is W, the load on each of the three wires is $W/3$.
When the middle wire breaks the load carried by each of the remaining two wires increases to $W/2$.

The load on each wire has increased by a factor of $\dfrac{\frac{W}{2}}{\frac{W}{3}} = \dfrac{3}{2}$.

As the wires obey Hooke's law, the extension of each wire must increase by the same factor i.e. the extension increases from 0.40 cm to 0.60 cm (answer **D**).

The change in the height h of the lamp above the floor is then 0.60 – 0.40 = 0.20 cm (answer **A**).

Question 20

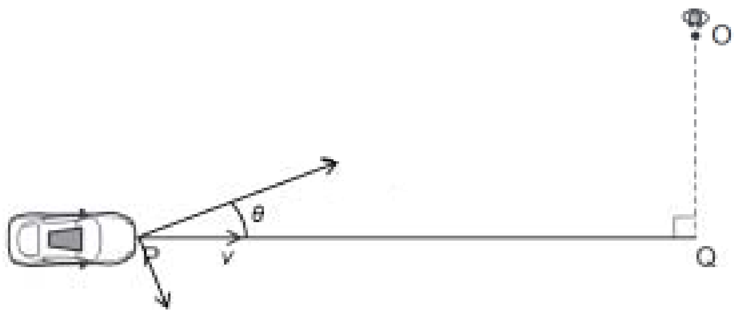
Candidates found this question challenging, with many candidates, stating that the *y*-gain should be decreased (answers **A** and **C**). The time-base is given in seconds per division, so increasing the time-base means the time taken for the trace to travel across the screen will also increase, so more of the sinusoidal waveform will be observed. The *y*-gain is given in volts per division, so increasing the *y*-gain will mean a smaller vertical displacement of the trace for a given potential difference (p.d.) and more of the waveform will be observed. To obtain a full sinusoidal waveform on the screen both the time-base and the *y*-gain should be increased (answer **D**).

Question 21

Most candidates recognised that *x* represents the amplitude (the maximum displacement of a particle) but some candidates answered that *y* was the wavelength, not the period of the oscillation of a particle. The *x*-axis is labelled time, so *y* must represent a time value.

Question 22

Candidates found this question very challenging. The majority deduced correctly that the frequency heard by the stationary observer would be greater than the frequency of sound *f* emitted by the loudspeaker on the car as the car is travelling towards the observer.



The component of the car's velocity travelling directly towards the observer is $v\cos\theta$.

As the car travels towards Q the value of θ increases, so $\cos\theta$, and hence $v\cos\theta$ decreases. The frequency heard by the observer will still be greater than *f* but will decrease as the car travels from P to Q (answer **C**).

Question 24

Candidates found this question challenging, with many candidates choosing the incorrect answers **B** or **D**. To answer this correctly, candidates needed to know Malus' law, noting that the angle between the vertically polarised light and the transmission axis of the polarising filter is **50°**. They also needed to recall that the intensity of a wave is proportional to the square of the amplitude of the wave.

If the intensity of polarised light reaching the polarising filter is I_0, then, from Malus' law, the intensity I transmitted by the filter is:

$$I = I_0 \cos^2 50 = 0.41$$

$$\frac{I}{I_0} = 0.41$$

Since intensity is proportional to amplitude squared:

$$\frac{A}{A_0} = \sqrt{\frac{I}{I_0}} = \sqrt{0.41} = 0.64 \text{ (answer } \mathbf{C}\text{).}$$

Question 25

This question was challenging. Many candidates confused the condition needed for the superposition of two waves with the conditions needed to produce stationary waves or the production of maxima and minima. For two waves to superpose, they simply need to be of the same type e.g. both sound waves or both water waves.

Question 26

Candidates who answered this question incorrectly frequently chose answers **B** or **D**. The key point to recall is that the speed *v* of waves on the string, traveling to and fro and superposing to form a stationary wave, is constant. As the frequency is increased, the next stationary wave is formed with 5 loops (6 nodes and 5 antinodes). If the length of the string is *L* and the new frequency is *f* ':

$$v = f\lambda = \frac{fL}{2} = \frac{f'L}{2.5} \Rightarrow f' = \frac{2.5}{2}f = 1.25f$$

Question 29

Candidates who answered this question incorrectly frequently chose answer **B**, using sin110° instead of sin55° in their calculation. Applying the diffraction grating equation:

$$n\lambda = s\sin\theta$$

where $n = 2$, $s = 1.0 \times 10^{-6}$ m and $\theta = 55°$:

$$\lambda = \frac{s\sin\theta}{n} = \frac{1.0\times10^{-6}\times\sin 55}{2} = 4.1\times10^{-7}\,\text{m}$$

which is answer **A**.

Question 33

Candidates who answered this question incorrectly frequently chose answer **A**, ignoring the change in the cross-sectional area of the wire when the wire is stretched. The key to this question is to realise that the product of the length of the wire and its cross-sectional area remains constant as the volume of the wire is constant. The fractional increase in the length of the wire is $\frac{2.65}{2.50}$ and the fractional decrease in the cross-sectional area of the wire is $\frac{2.50}{2.65}$.

For the unstretched wire: $$R = \frac{\rho L}{A} = \frac{3.50\times10^{-7}\times2.50}{4.50\times10^{-6}} = 0.194\,\Omega$$

For the stretched wire: $$R' = \frac{\rho L}{A} = \frac{3.50\times10^{-7}\times2.65}{4.50\times10^{-6}\times\left(\frac{2.50}{2.65}\right)} = 0.218\,\Omega$$

The change in the resistance of the wire = $R' - R$ = 0.218 – 0.194 = 0.024 Ω (answer **B**)

Question 35

Candidates found this question challenging, with the many candidates deciding that one of the readings would decrease while the other stayed the same (answers **B** and **C**).

For the circuit given in the question:

$$E = i\,(R+r)$$

where i is the current in the circuit. The reading on the ammeter is $i = \dfrac{E}{R+r}$.

As r increases, i **decreases**.

The reading on the voltmeter is iR. As i decreases and R is constant, the reading on the voltmeter also **decreases** (answer **A**).

Question 36

Careful application of the rule for adding up resistances in parallel is needed to find the correct answer to this question.

In **A** the supply p.d. is shared equally between the two equal resistors, so $V = 4.5\,\text{V}$.

In **B** $\dfrac{2}{3}$ of the supply p.d. is across the resistor of resistance $2X$, so $V = 6\,\text{V}$.

In **C** the parallel resistors have a combined resistance of $\dfrac{2}{3}X$, so the output voltage V is given by:

$$\frac{\left(\frac{2}{3}X\right)}{\left(\frac{5}{3}X\right)} \times 9 = 3.6\,\text{V} .$$

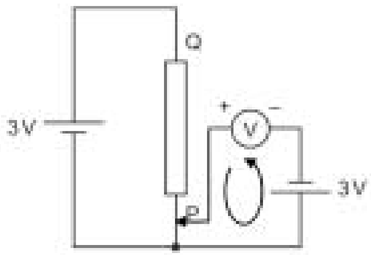
In **D** the parallel resistors again have a combined resistance of $\dfrac{2}{3}X$ and the output voltage V is given by:

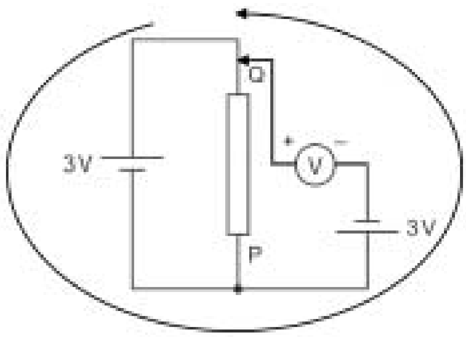
$$\frac{X}{\left(\frac{5}{3}X\right)} \times 9 = 5.4\,\text{V} .$$

The circuit with the largest output voltage is **B**.

Question 37

One approach to this question is to apply Kirchhoff's 2^{nd} law around a closed loop of the circuit when the contact is at end P and then at end Q.





In the first circuit, the reading on the voltmeter = 3 V
In the second circuit, the reading on the voltmeter is 3 + 3 = 6 V
The correct answer is **D**.

PHYSICS

Paper 9702/12
Multiple Choice

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

Candidates found **Questions 12, 28, 29, 36 and 39** particularly difficult, but found **Questions 2, 14, 15, 18, 35 and 38** relatively straightforward.

Comments on specific questions

Question 1

Most candidates answered this question correctly. Candidates needed to recall that the density of water is approximately 1×10^3 kg m^{-3}. The stone, because it sinks in water, must have a density greater than that of water.

Question 6

Most candidates answered this question correctly, though candidates who answered incorrectly frequently chose answer **D**. When either rock reaches its maximum height, its velocity is zero. The maximum height is the area under the velocity-time graph from time $t = 0$ to the first time at which the rock has zero velocity. This is 7.2 m for Earth and 19.2 m for Mars. The **difference** in the two heights reached is 19.2 – 7.2 = 12 m (answer **A**).

Question 8

Around half the candidates answered this question correctly.

When the submarine is at rest, the upthrust U equals the weight of the submarine, $3200g$ N.

When 200 kg of water is pumped from the submarine, its mass decreases to 3000 kg and its weight decreases to $3000g$ N. The upthrust on the submarine remains the same (the submarine is displacing the same volume of water), so applying $F = ma$:

$$3200g - 3000g = 3000a$$

so $a = 0.654$ m s^{-2}, where a is the initial upward acceleration of the submarine (answer **B**).

Question 11

Most candidates calculated the moment of the force F about O correctly ($F \times$ distance OY, answer **B**), though candidates who answered incorrectly frequently chose $F \times$ WO (answer **C**). It is important to recall that the moment of a force F about a point is the magnitude of F multiplied by the **perpendicular distance** of F from the point.

Question 12

Candidates found this question challenging, with **D** the most popular incorrect answer. Applying the principle of moments about point X:

$F \times l \sin 30 = 10.0 \times \dfrac{1}{2}$ where l is the length of the rod.

$\Rightarrow F = 10$ N (Answer **C**)

Candidates who selected answer **D** as the answer may have considered the weight of the uniform rod acting through point Y rather than the centre of the rod.

Question 16

Half the candidates answered this question correctly, with graph **B** the most frequently chosen incorrect answer. Candidates need to recall the equation:

$$\text{power} = \text{force} \times \text{velocity}\ (p = Fv)$$

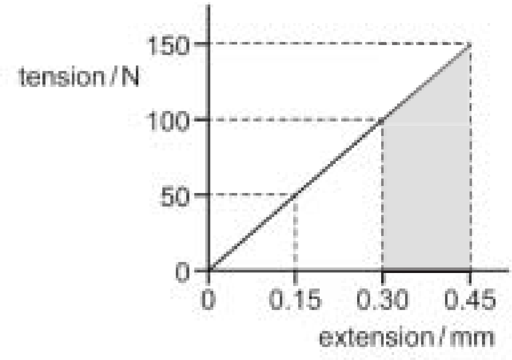
If the power p supplied to the train is constant, then $F \propto \dfrac{1}{v}$ i.e. as v increases, F decreases (graph **A**).

Question 19

Most candidates answered this question correctly (answer **B**) with answer **A** the most frequently chosen incorrect answer. The **extra** elastic potential energy in the wire is represented by the extra area under the graph, from an extension of 0.30 mm to an extension of 0.45 mm.

The extra area is given by:

$$\frac{1}{2}\times(150+100)\times0.15\times10^{-3}=0.019\text{ J}$$



Question 23

Candidates should know the typical wavelengths of the principal regions of the electromagnetic spectrum from radio waves to γ-rays, and recall that wavelengths in the range 400 – 700 nm are visible to the human eye. The corresponding frequencies can then be calculated from $c = f\lambda$, where c is the speed of light. In this question, a wavelength of 600 nm corresponds to a frequency of $\frac{3\times10^{8}}{600\times10^{-9}} = 5\times10^{14}$ Hz (Answer **D**).

Question 24

Around half the candidates answered this question correctly. From Malus' law, the intensity of light I_1 passing through the first polarising filter is:

$$I_1 = I_0 \cos^2 45$$

The transmission axis of the second filter is at 45° to the transmission axis of the first filter. The intensity of light I_2 passing through the second filter is therefore:

$$I_2 = I_1 \cos^2 45 = (I_0 \cos^2 45) \cos^2 45 = \frac{1}{4} I_0 \text{ (Answer } \mathbf{B}\text{)}$$

Question 28

Candidates found this question challenging, with **B** being the most popular incorrect answer. Candidates need to recall that there is a (zero order) maximum at the centre of the fringe pattern where two light waves, of equal amplitude, are in phase and interfere constructively. Covering one of the slits reduces the amplitude of one of the waves to zero. Recalling that the intensity of a wave is proportional to the square of the amplitude of the wave, halving the amplitude reduces the intensity by a factor of 4.

The new intensity is $\frac{I}{4}$ (answer **D**).

Question 29

Candidates found this question challenging, with answers **A** or **B** the most frequently selected incorrect answers. Recalling the diffraction grating equation:

$$n\lambda = s\sin\theta$$

where n = 3, λ = 550 nm and $\theta = \tan^{-1}\left(\frac{0.75}{3.5}\right) = 12.1°$

$$s = \frac{n\lambda}{\sin\theta} = \frac{3\times550\times10^{-9}}{\sin 12.1} = 7.7\times10^{-6}\text{ m} \quad \text{(answer } \mathbf{C}\text{)}$$

Candidates selecting **A** calculated s for n = 1; those who selected **B** used $\theta = \sin^{-1}\left(\frac{0.75}{3.5}\right)$.

Question 30

Around half the candidates answered this question correctly. Candidates should understand that the charge on any charge carrier is quantised i.e. the charge carried must be a multiple of the electronic charge, e. In this question, only **C** (4.8×10^{-19} C) is a multiple of the electronic charge, 1.6×10^{-19} C.

Question 32

The simplest way to calculate the resistivity is to realise that the 9 strands of copper wire are equivalent to one strand of wire with cross-sectional area $12A$.

$$R = \frac{\rho L}{12A} \qquad \rho = \frac{12AR}{L}$$

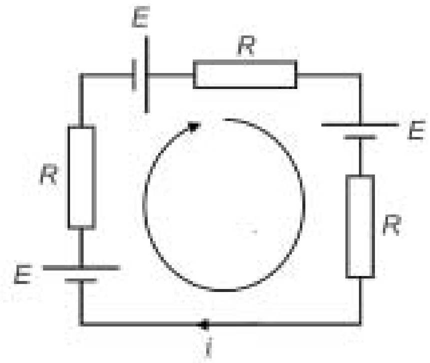
where ρ is the resistivity of the copper wire (answer **D**). Note also that **A** and **B** cannot be correct as they would have units of mΩ^{-1} not Ωm.

Question 33

Almost all the candidates decided that the resistance of one of the components would increase and the other would decrease, but some candidates decided the resistance of the LDR would increase and the resistance of the thermistor would decrease (answer **B**). As the light intensity incident on the LDR increases, its resistance decreases; as the thermistor moves from a warm to a cold environment its resistance will increase (answer **C**).

Question 36

Candidates found this question challenging. The key point to notice is that the polarity of one of the cells is the opposite of the other two.



Applying Kirchhoff's 2nd law around the closed loop of the circuit:

$$E + E - E = 3iR$$
$$i = \frac{E}{3R}$$

where i is the current in the circuit.

The potential difference (p.d.) across any one of the resistors is $iR = \frac{E}{3}$ (answer **B**).

Question 37

Candidates found this question challenging, and the most frequent incorrect answer was deciding that the sliding contact should be moved to the right rather than the left (answer **D**).

When the LDR is covered its resistance increases. For the ammeter to again read zero, the resistance of the wire to the right of the sliding contact must increase relative to the resistance of the wire to the left of the sliding contact i.e. the sliding contact must be moved to the left (answer **C**).

Question 39

To answer this question, candidate needed to include the neutron that is fired at the uranium nucleus in their calculation of the total number of free electrons when the nucleus splits.

The uranium $^{235}_{92}U$ nucleus contains (235 – 92) = 143 neutrons. The barium $^{141}_{56}Ba$ nucleus contains (141 – 56) = 85 neutrons and the krypton $^{92}_{36}Kr$ nucleus contains (92 – 36) = 56 neutrons.

The total number of 'free' electrons after the uranium nucleus splits = 1 +143 – 85 – 56 = 3.

PHYSICS

Paper 9702/13
Multiple Choice

Question Number	Key	Question Number	Key	Question Number	Key	Question Number	Key
1	C	11	B	21	D	31	D
2	A	12	C	22	D	32	B
3	D	13	D	23	B	33	B
4	A	14	A	24	C	34	A
5	C	15	C	25	B	35	A
6	D	16	C	26	A	36	C
7	B	17	D	27	C	37	A
8	B	18	B	28	B	38	D
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General comments

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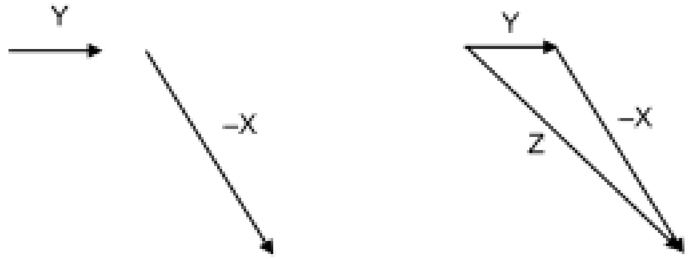
Candidates found **Questions 8, 9, 14, 26, 29 and 34** particularly difficult, but found **Questions 3, 13, 21, 22, 25 and 35** relatively straightforward.

Comments on specific questions

Question 1

Just over half the candidates answered this question correctly, though some thought that a physical quantity must include an SI unit, or a unit expressed in base units.

Question 4
Candidates found this question challenging. If X = Y – Z then Z = Y – X.



The correct answer is **A**. In **B**, the vector drawn is X – Y; in **C**, X + Y; in **D,** –X – Y.

Question 7

Candidates found this question challenging. One approach is to consider what happens in one second.

volume of paint ejected in one second = $400 \times (0.4 \times 10^{-6}) \times 2.5 = 4.0 \times 10^{-4}\,\text{m}^3$

mass of paint ejected in one second = $\rho V = 900 \times 4.0 \times 10^{-4} = 0.36\,\text{kg}$

change of momentum of paint in one second = $0.36 \times 2.5 = 0.90\,\text{kg m s}^{-1}$

From Newton's second law of motion, force equals the rate of change of momentum (the change in momentum in one second) so the horizontal force needed to keep the device stationary is 0.90 N. (Answer **B**). Candidates selecting **A** omitted the density in their calculation, while those selecting **C** included the density twice. Those selecting **D** made a power-of-ten error when converting mm^2 into m^2.

Question 8

Candidates found this question very challenging. Two key points need to be understood when applying Newton's third law of motion:
- The two forces are of the **same type**;
- The two forces act on **different objects**.

In **A** the two forces may be equal (if the car is travelling at constant speed) but both forces act on the car. In **D** the two forces shown both act on the aeroplane. In **C** the two forces are equal if the block is at rest, but both forces act on the block. Only **B** satisfies the criteria for applying Newton's third law – the two forces are of the same type (gravitational) and act on different objects (the Earth and the Moon).

Question 9

Most candidates found this question challenging. The sum of the upward forces acting on a ball is equal to its weight – the net force on either ball is zero, so the balls fall at constant speed and answers **A** and **B** can be ruled out.

For the lighter mass m: $D + U = mg$ where D is the drag force on the ball and U the upthrust.

Similarly, for the heavier mass M: $D + U = Mg$

U is the same for both balls (they have the same shape and size so displace the same amount of liquid) but $Mg > mg$ so the drag force D on the heavier ball must be greater.

For D to be greater for the heavier ball, it must be falling faster than the lighter ball (candidates need to recall that drag force increases as speed increases).

Question 10

Most the candidates answered this question correctly, though some may have made sign errors when applying the *velocity of approach equals velocity of separation* rule for perfectly elastic collisions.
There are three possible approaches to finding the kinetic energy of Y: If V is the velocity of Y after the collision:

1. Conservation of momentum.

$$4mV - \frac{3mv}{5} = mv \Rightarrow V = \frac{2v}{5} \Rightarrow \text{k.e. of Y} = \frac{1}{2}4m\left(\frac{2v}{5}\right)^2 = \frac{16}{50}mv^2$$

2. Conservation of k.e.

$$\Delta\text{k.e.} = \frac{1}{2}mv^2 - \frac{1}{2}m\left(\frac{3v}{5}\right)^2 = \frac{16}{50}mv^2$$

3. Velocity of separation = velocity of approach:

$$V + \frac{3v}{5} = v \qquad V = \frac{2v}{5} \qquad \text{k.e. of Y} = \frac{16}{50}mv^2$$ (answer **C**)

Question 14

Candidates found this question challenging. Candidates need to recall Archimedes' principle: that the upthrust F_u on an object in a fluid is equal to the weight of the liquid displaced by the object, W_L (answer **A**).

Question 15

Around half of the candidates answered this correctly (answer **C**). The most frequent incorrect answer was **B**: *moving the suitcase 16 m at a constant speed along the horizontal conveyor belt*

In this instance no work is done on the suitcase since the suitcase acquires no extra energy (the weight force acting on the suitcase and the direction of movement are at right angles).

Question 17

Around half of the candidates answered this question correctly. The most frequent incorrect answer was thinking that the object has zero kinetic energy at its maximum height i.e. that the object is at rest, ignoring the (constant) horizontal component of velocity.

Question 19

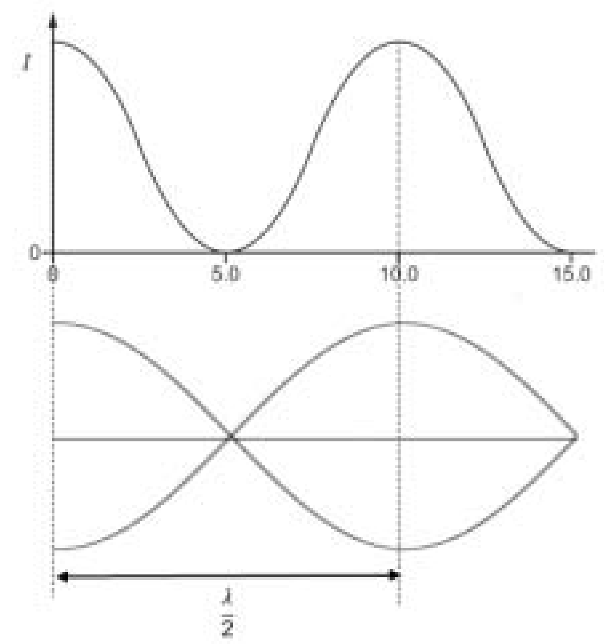
Most candidates answered this question correctly, recognising that the work done in stretching the wire is the area under the graph, $\frac{1}{2}F(L_1 - L_0)$ (answer **B**), though some just used *work done equals force $\times$ distance*, and obtained a value which was twice the correct value (answer **D**).

Question 23

Around half of the candidates answered this question correctly. Some candidates thought waves of wavelength 2.1 cm are radio waves rather than microwaves. Candidates should be able to recall the approximate range of wavelengths in free space of the principal regions of the electromagnetic spectrum from radio waves to γ-rays. The wavelengths of microwaves are in the range 1 mm to 30 cm; the wavelengths of radio waves are in the range 30 cm to 100 km.

Question 26

This question proved to be very challenging, with many candidates selecting answer **C** rather than the correct answer **A**. This can be considered in the same way as a stationary sound wave in a pipe, the distance between two successive loud sounds (intensity maxima) being half the wavelength.



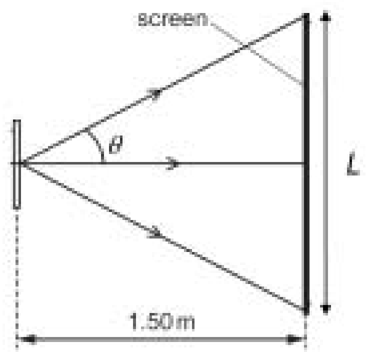
From the diagram, $\frac{\lambda}{2} = 0.10\,\text{m}$ $f = \frac{v}{\lambda} = \frac{340}{0.20} = 1700\,\text{Hz}$

Question 29

Many candidates found this question challenging. Using the diffraction grating equation:

$n\lambda = s\sin\theta$ where $n = 3$, $\lambda = 600\,\text{nm}$ and $s = 2.0 \times 10^{-6}\,\text{m}$:

$$\sin\theta = \frac{n\lambda}{s} = \frac{3\times600\times10^{-9}}{2.0\times10^{-6}} = 0.90 \qquad \theta = 64.2$$



distance between one end and the centre of the screen, $\frac{L}{2}$ = 1.50 × tan64.2 = 3.1 m

distance between the two ends of the screen, L = 3.1 × 2 = 6.2 m (Answer **D**)

Candidates selecting **C** forgot to double the distance from one end of the screen to the centre of the screen. Candidates selecting **A** used $\sin\theta$ rather than $\tan\theta$ in their calculations, while candidates selecting **B** made both these errors.

Question 34

Most candidates found this question challenging with **C** and **D** the most popular incorrect answers. The key to answering this question is to realise that the two resistors in parallel must have a combined resistance which is smaller than the resistance of either of the individual resistors. If the two resistors have resistances R_1 and R_2 the combined resistance of the two resistors in parallel is:

$$\frac{R_1R_2}{R_1+R_2}=R_1-\frac{R_1^2}{R_1+R_2}<R_1$$

When the switch S is closed the current in the circuit increases, so the ammeter reading increases. The terminal potential difference (p.d.) '$E - iR$', where E is the electromotive force (e.m.f.) of the battery, must decrease. The voltmeter measures the terminal p.d. (the potential difference between the two terminals of the battery) so must decrease (answer **A**).

Question 37

The most frequently selected incorrect answers were **C** and **D**. For the galvanometer to read zero, the electromotive force (e.m.f.) of cell X must be equal to the potential difference between points Q and P on the resistance wire.

From the circuit, as the resistance wire is uniform, when the galvanometer reading is zero:

$$\frac{V_{QP}}{V_{QR}}=\frac{QP}{QR}=\frac{0.5}{2.0} \qquad QP=\frac{QR}{4}$$ (answer **A**)

PHYSICS

Paper 9702/21
AS Level Structured Questions 21

Key messages

- If a final numerical answer is incorrect, partial credit may sometimes be awarded for a clearly presented supporting calculation. No credit may be awarded for an incorrect final answer without supporting working, so candidates should be encouraged to show their working clearly.

- In numerical calculations, candidates should remember to first write down the appropriate symbol equation before substituting in the relevant values. If the equation is rearranged, the new subject of the equation should always be stated.

- Candidates should be aware that prematurely rounding any intermediate answers in the middle of a calculation can cause the final numerical answer to be incorrect.

- Candidates need to be able to recall definitions and the meanings of the terms in the syllabus. A significant number of marks may be obtained by candidates who are able to demonstrate accurate recall. The omission of one or two key words from a definition may prevent credit from being awarded.

- When drawing a graph line, candidates should ensure that the line is drawn as carefully as possible. A ruler should be used to draw a line that is meant to be straight. If the line is meant to go through the origin or another key point, it is essential that the line is drawn precisely through that point.

General comments

There were many opportunities for the weaker candidates to show their knowledge and understanding in the straightforward parts of questions. For example, **Questions 1(a)**, **2(a)(i)**, **2(c)(i)**, **3(a)**, **5(a)**, **5(b)(i)**, **7(d)(i)** and **8(a)(i)**. There were also more demanding parts of questions where the application of basic knowledge was required. Examples of these included **2(b), 2(c)(ii)**, **3(c)**, **4(c)**, **4(d)**, **6(b)** and **7(b)**.

In **Question 7**, many candidates found it difficult to apply their understanding to an electric circuit consisting of resistors connected in series with a battery. The relationship between the potential difference across each resistor and its value of resistance was not well understood. Those candidates would have benefited from further practice in answering past paper questions that involve the principle of a potential divider circuit.

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

Comments on specific questions

Question 1

(a) (i) Most candidates defined power correctly. A small minority stated ‘force × velocity’ which is a consequence of the definition but is not the definition itself.

(ii) The majority of the candidates successfully combined the base units of force with the base units of distance and time to give the base units of work done per unit time and hence find the base units of power. A small minority of the candidates stated the appropriate symbol equation for power, but did not substitute the base units into that equation.

(b) Some of the weaker candidates wrongly assumed that the base unit of frequency was hertz. Another common mistake was to use the ampere as the base unit of intensity, presumably because the symbol I may be used to represent both intensity and current. Many candidates found it challenging to combine the base units after they had been substituted into the given equation.

Question 2

(a) (i) The calculation of the vertical component of the tension in the string was usually shown correctly.

(ii) Most candidates were able to calculate at least one of the moments about the hinge. A common mistake was to use the wrong perpendicular distance to the hinge of a force when calculating the corresponding moment. Another common mistake was to treat a clockwise moment as being in the anticlockwise direction (or vice versa).

(iii) Stronger candidates realised that the horizontal component of the force exerted on the beam by the hinge must be equal in magnitude to the horizontal component of the tension in the string because the beam is in equilibrium. Many of the weaker candidates made inappropriate attempts to combine the vertical forces acting on the beam to determine the horizontal component of the force exerted on the beam by the hinge.

(b) Most candidates were able to recall the appropriate symbol equation $E = \frac{1}{2}Fx$. A common mistake was to then substitute the wrong value of the force. Some candidates gave an answer that had only one significant figure, even though the data in the question indicated that two significant figures were appropriate.

(c) (i) The majority of the responses began with the correct symbol equation for the change in gravitational potential energy. Some of the weakest candidates confused the mass of the block with its weight.

(ii) The symbol formula for kinetic energy was usually recalled correctly. There were different methods of calculating the speed of the block at point A. The most common method was to first determine the kinetic energy at point A by using the kinetic energy at point B and the decrease in gravitational potential energy that had been calculated in **(c)(i)**. A significant number of the candidates incorrectly gave the speed of the block at point B, instead of at point A, as their final answer.

(iii) The question asked for an answer that referred to the force acting on the block. It was therefore insufficient to only explain that there was no acceleration in the horizontal direction. A common answer was that there was no resultant force at all on the block, which is incorrect as there is a resultant force due to the block's weight. Stronger candidates correctly explained either that there was no resultant horizontal force or that the weight acted only in the vertical direction.

(iv) Only a minority of the candidates were able to sketch the correct graph. A common mistake was to sketch a straight line with a positive gradient starting from the origin rather than from a non-zero value of v_Y. A significant number of candidates drew a line with a negative gradient, which incorrectly assumes that the block is decelerating rather than accelerating.

Question 3

(a) A common mistake was to state Newton's second law of motion as 'force is equal to mass × acceleration'. This is a simplification of the law in which mass is assumed to be constant. A small proportion of the candidates inappropriately stated Newton's first or third laws of motion.

(b) (i) Most candidates correctly determined the resultant force from the gradient of the graph line.

(ii) A common mistake was to calculate the magnitude of force X by subtracting, instead of adding, the magnitude of the frictional force and the magnitude of the resultant force.

(c) Most candidates found it challenging to sketch the correct graph.

Question 4

(a) The majority of the candidates were able to give the correct symbol formulae for density and pressure. Weaker candidates often found it difficult to then manipulate the algebra to obtain the required answer. Some candidates made irrelevant attempts to check the homogeneity of the given equation using SI base units.

(b) The majority of the candidates gave a correct response.

(c) A common mistake was to do the calculation using a single value of pressure instead of the change in pressure. Some candidates omitted the value of the acceleration of free fall from their calculation. Others had a power-of-ten error in their values of pressure or their value of depth.

(d) It was expected that the candidates would calculate the new tension in the wire by subtracting the magnitude of the upthrust from the magnitude of the original tension. A common error was to give the magnitude of the upthrust as the new tension in the wire.

Question 5

(a) (i) The most common incorrect answers were ‘ultraviolet’ and ‘visible’. Some candidates did not seem to be aware of the meaning of the electromagnetic spectrum. A significant number of the candidates did not attempt a response.

(ii) The frequency was usually calculated correctly, although weaker candidates sometimes found it difficult to convert the units from Hz to THz.

(b) (i) There were many correct responses. Common incorrect answers were ‘same amplitude’ and ‘same path difference’ and these were not given credit.

(ii) Most candidates were able to recall the correct symbol equation. A significant number of the candidates were unable to determine the correct value of the fringe width from the data given in the question.

(c) (i) Many candidates did not understand that the path difference between the waves is equal to half of one wavelength. A significant number of the candidates did not attempt a response.

(ii) Stronger candidates usually gave the correct answer. A common incorrect answer was 180°.

Question 6

(a) Many of the weaker candidates did not understand that ‘number density’ means the number of free electrons per unit volume.

(b) Most candidates were able to do the first step of the calculation by correctly determining the current. However, many candidates subsequently confused the total number of free electrons in the wire with the number density of the free electrons. A significant number did not attempt a response.

Question 7

(a) Many candidates calculated the wrong value of the current. A common mistake was to assume that the potential difference across the resistor of resistance 5800 Ω was either 6.0 V or 9.6 V instead of 3.6 V.

(b) The circuit diagram showed that the battery and resistors were connected in series. For this arrangement, many candidates did not understand the relationship between the potential difference across each resistor and its value of resistance. Some candidates wrongly assumed that the current in the thermistor had a different value to the current in the resistor of resistance 5800 Ω. A significant number of the candidates did not attempt a response.

(c) Although some of the candidates were able to calculate the energy transferred from the battery, many did not realise that they then needed to subtract this transferred energy from the initial energy stored in the battery.

(d) (i) This question was usually answered correctly.

(ii) A significant number of the candidates were not able to deduce how the increase in the resistance of the thermistor would affect the current in it.

(iii) Weaker candidates found it difficult to apply their understanding of potential divider circuits to this part of the question.

Question 8

(a) (i) Most candidates correctly stated that the nuclei would have the same charge. Many did not include a supporting explanation that explicitly compared the number of protons in each nucleus. When questions use the command words ‘state and explain’, it is essential that an explanation is given as well as a final statement.

(ii) Many responses did not include an explanation that compared the number of protons in each nucleus. Some candidates wrote comments in such a way that it was ambiguous whether those comments referred to nucleus X or to nucleus Y. Some of the weakest candidates sometimes demonstrated the misconception that there are electrons in the nucleus.

(b) The majority of the candidates stated the principle of conservation of momentum without applying it to the decay of nucleus X. Only the strongest candidates realised that the initial momentum of X was zero. Very few candidates understood that the momentum of nucleus Y had to be equal to the momentum of the alpha-particle. A significant number of candidates did not attempt a response.

PHYSICS

Paper 9702/22
AS Level Structured Questions 22

Key messages

- If a final numerical answer is incorrect, partial credit may sometimes be awarded for a clearly presented supporting calculation. No credit may be awarded for an incorrect final answer without supporting working, so candidates should be encouraged to show their working clearly.
- In numerical calculations, candidates should remember to first write down the appropriate symbol equation before substituting in the relevant values. If the equation is rearranged, the new subject of the equation should always be stated.
- Candidates should be aware that prematurely rounding any intermediate answers in the middle of a calculation can cause the final numerical answer to be incorrect.
- Candidates need to be able to recall definitions and the meanings of the terms in the syllabus. A significant number of marks may be obtained by candidates who are able to demonstrate accurate recall. The omission of one or two key words from a definition may prevent credit from being awarded.
- When drawing a graph line, candidates should ensure that the line is drawn as carefully as possible. A ruler should be used to draw a line that is meant to be straight. If the line is meant to go through the origin or another key point, it is essential that the line is drawn precisely through that point.

General comments

There were many parts of questions that were straightforward to answer so that weaker candidates had opportunities to be awarded credit. Other question parts were more challenging and suitable for the stronger candidates. In **Question 5(b)(iii)**, many candidates did not know how to determine the maximum wavelength of a stationary sound wave that can be produced using a tube closed at one end. In **Question 5(c)(ii)**, most of the candidates would have benefited from having a greater understanding of how the intensity of polarised light changes when passing through two polarising filters. In **Question 6(a)**, many candidates did not understand how the resistance of a filament lamp would change when the current in it is decreased. In **Question 6(b)**, many candidates would have benefited from having a deeper understanding of the quantitative relationship between the electric current and the average drift speed of the free electrons in a wire.

There was no evidence well-prepared candidates being short of time to complete the paper.

Comments on specific questions

Question 1

(a) (i) The correct definition of pressure was usually given.

(ii) The majority of the candidates found it very straightforward to show how the SI base units of pressure are determined.

(b) The SI base units of the individual quantities in the given equation were usually stated correctly. Weaker candidates often had difficulty combining those base units to determine the final answer. A common mistake was to assume that the difference in pressure ($p_2 – p_1$) had no base units instead of the base units of pressure.

(c) Successful responses included a concise, focused explanation of why *R* would contribute more to the percentage uncertainty in the calculated value of *k*. Many candidates gave vague or incomplete explanations. It was insufficient to just state that *R* is raised to the power of 4 without also explaining that this would mean that the percentage uncertainty in *R* would be multiplied by 4.

Question 2

(a) Although this part of the question could be answered using straightforward recall, it was essential to give a precise statement. A common misconception was that the centre of gravity of an object is the point where all the weight actually acts, rather than the point where all the weight *is taken to* act. Some candidates inappropriately referred to 'mass' instead of 'weight' in their response.

(b) (i) The principle of moments was usually applied correctly. Some candidates were unable to calculate the component of the tension perpendicular to the beam. Other candidates forgot that this component of the tension needed to be multiplied by its distance to the pivot in order to calculate its moment.

(ii) The resultant moment about the pivot was usually calculated correctly. The most common error was to add the moments of the weights of the blocks rather than to subtract them.

(c) (i) The majority of the answers were correct. Some of the weakest candidates confused the mass of the block with its weight.

(ii) Almost all of the candidates were able to calculate the kinetic energy of the block at point X. Many candidates were not able to correctly combine this with the change in gravitational potential energy calculated in **(c)(i)** in order to determine the kinetic energy of the block at point Y. Some of the weakest candidates were able to recall the correct symbol formula for kinetic energy, but then substituted the value of the weight of the block as its mass. A very small number of candidates attempted an alternative method of calculation that involved first calculating the speed of the block at Y and then using that speed to determine the kinetic energy at that point.

(iii) Only the strongest candidates realised that there would be no variation in the direction of the acceleration of the block. Some candidates vaguely described the acceleration as being always 'downwards' rather than always '*vertically* downwards'.

(iv) Weaker candidates often drew inappropriate upward or downward sloping lines. Stronger candidates usually realised that they need to draw a horizontal straight line at a non-zero value of velocity. Candidates should be encouraged to use a ruler to draw straight lines.

Question 3

(a) (i) A significant minority of the candidates incorrectly stated 'mass × acceleration'. This is a method of calculating force, but it is not the definition of force required by the syllabus.

(ii) The stronger candidates found it straightforward to calculate the change in momentum by multiplying the resultant force by the corresponding time interval. A common error was to use only the driving force *X* instead of the resultant force in the calculation.

(b) (i) Weaker candidates found it difficult to apply Newton's laws of motion to this part of the question. Many candidates correctly stated that the block would have a constant velocity, although others sometimes incorrectly stated that the block's velocity would decrease to zero. Only the stronger candidates could explain that there was constant velocity because there was no resultant force acting on the block.

(ii) Generally, this question was well answered. Very weak candidates sometimes confused the power with the work done.

(c) Many candidates correctly deduced that for the first 3.0 s the graph would be an upward sloping straight line from the origin. The rest of the graph line was often drawn incorrectly. A common mistake was to draw a graph line with a step change in momentum at 3.0 s. Another common error was to draw a downward sloping line after 3.0 s.

Question 4

(a) Almost all of the responses were correct.

(b) The appropriate symbol equation was usually stated correctly. Some candidates forgot to convert the units of the extension from cm to m and therefore made a power-of-ten error. Candidates should always carefully check the units of any readings that they take from graph scales.

(c) Most candidates were able to state an appropriate symbol equation for the elastic potential energy. As in the previous question part, some candidates made a power-of-ten error. Another common mistake was to substitute the value of the total length of the spring instead of its extension.

Question 5

(a) (i) Successful responses were concise and unambiguous. Weaker candidates often gave a convoluted and confused general description of a transverse wave without directly comparing the directions of lines P and Q.

(ii) Weaker candidates sometimes attempted to give a general description of a longitudinal wave without directly comparing the directions of lines P and Q.

(b) (i) This question was generally well answered. A very small minority of the candidates did not convert the units of the frequency from kHz to Hz and so gave an incorrect answer that had a power-of-ten error.

(ii) Stronger candidates found it straightforward to calculate the length of the tube. A significant number of the weaker candidates were unable to use the stationary wave pattern to deduce the relationship between the length of the tube and the wavelength of the stationary wave.

(iii) Many candidates did not know how to determine the maximum wavelength of a stationary sound wave that can be produced using a tube closed at one end. Many candidates did not show a calculation and simply guessed an answer. Others did not attempt a response at all.

(c) (i) Malus's law was usually applied correctly. The question used the command word 'show' and so it was essential that the candidates carefully presented the full calculation as well as stating the final answer.

(ii) Most of the candidates would have benefited from having a greater understanding of how the intensity of polarised light changes when passing through two polarising filters that are at different angles to the plane of polarisation of the light in the incident beam. Many candidates were able to calculate an angle of 17°, but did not realise that they then needed to add this to 35° to calculate the correct answer of 52°. A significant number of the weakest candidates did not attempt a response.

Question 6

(a) Only a small minority of the candidates correctly linked the decrease in current to a decrease in temperature so that there would be a decrease in resistance of the lamp. Many candidates made confused and inappropriate attempts to apply Ohm's law and often thought that the resistance would increase because it would be inversely proportional to the current.

(b) (i) Generally, this question was well answered.

(ii) Only the strongest candidates were able to determine the correct expression for the average drift speed of the free electrons. Many candidates confused the total number of free electrons in the wire with the number density of the free electrons. Some candidates introduced the symbol V to represent the volume of the wire and then confused this with the symbol V that was used to represent the potential difference between the ends of the wire.

(iii) Candidates that had answered the previous part correctly usually went on to determine the correct expression here. However, many candidates found this part of the question to be very challenging and a significant number did not attempt a response.

Question 7

(a) Most candidates understood the principle of a potential divider circuit and so the correct answer was usually given.

(b) (i) Weaker candidates found it challenging to apply the principle of the potentiometer as a means of comparing potential differences. Those candidates would have benefited from having a greater understanding of potentiometer circuits. Practising answering past paper questions on this topic is an effective way for candidates to gain a deeper understanding.

(ii) It was generally understood that the intensity of the light illuminating the LDR would increase. Most candidates correctly stated that the total power produced by the battery would increase, although a common misconception was that the power would stay the same. Only the strongest candidates were able to deduce that length XZ would decrease.

Question 8

(a) (i) Generally, this question was well answered. Weaker candidates sometimes gave vague answers that did not directly compare nucleus P with nucleus Q. Other candidates did not read the question carefully and compared nucleus Q with nucleus R.

(ii) Most candidates correctly deduced that a down quark changes to an up quark. The most common incorrect answer was that an up quark changes to a down quark. Very weak candidates sometimes stated only the quark composition of a single nucleon instead of stating the *change to* the quark composition.

(iii) The emitted particle was usually identified correctly as an antineutrino. The most common incorrect answer was a neutrino.

(b) The charges of the charm and bottom quarks were generally well known so that the overall charge of the hadron was usually calculated correctly.

PHYSICS

Paper 9702/23
AS Level Structured Questions 23

Key messages

- If a final numerical answer is incorrect, partial credit may sometimes be awarded for a clearly presented supporting calculation. No credit may be awarded for an incorrect final answer without supporting working, so candidates should be encouraged to show their working clearly.
- In numerical calculations, candidates should remember to first write down the appropriate symbol equation before substituting in the relevant values. If the equation is rearranged, the new subject of the equation should always be stated.
- Candidates should be aware that prematurely rounding any intermediate answers in the middle of a calculation can cause the final numerical answer to be incorrect.
- Candidates need to be able to recall definitions and the meanings of the terms in the syllabus. A significant number of marks may be obtained by candidates who are able to demonstrate accurate recall. The omission of one or two key words from a definition may prevent credit from being awarded.
- When drawing a graph line, candidates should ensure that the line is drawn as carefully as possible. A ruler should be used to draw a line that is meant to be straight. If the line is meant to go through the origin or another key point, it is essential that the line is drawn precisely through that point.

General comments

There were many opportunities for the weaker candidates to show their knowledge and understanding in the straightforward parts of questions, such as in **Questions 3(a)**, **3(c)(i)**, **4(b)(ii)**, **4(d)(i)**, **5(a)**, **6(a)**, **7(a)** and **7(c)**. There were also more demanding parts of questions where the application of basic knowledge was required. Examples of these included **Questions 2(a)**, **2(b)**, **3(b)**, **4(b)(i)**, **4(c)**, **5(c)**.

In **Question 5**, many candidates found it difficult to apply their understanding of electric circuits. Those candidates would have benefited from further practice in answering past paper questions involving components connected in series to a power supply. This would have given them a deeper understanding of the principle of a potential divider circuit.

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

Comments on specific questions

Question 1

(a) This question was well answered by most candidates. Weaker candidates sometimes used an inappropriate equation that assumes constant velocity instead of constant acceleration.

(b) The majority of the candidates were able to give at least one reason for the recorded time being inaccurate. Some candidates gave reasons that were too general, such as ‘human error’ or ‘not using the stop-watch correctly’. The candidates needed to give reasons that were specific to the method of timing the stone falling down the well.

(c) The majority of the candidates were able to explain why the readings were precise but not accurate.

Question 2

(a) A significant number of the stronger candidates correctly deduced that the density of the sphere is 21% of the density of the sea water. Many candidates were able to derive an expression for the weight of the sphere. Weaker candidates often had difficulty forming an equation that linked the weight of the sphere to an upthrust that was due to only 21% of the volume of the sphere being submerged.

(b) (i) The majority of the candidates found it difficult to derive an expression for the resultant force on the sphere in terms of the upthrust and the weight. Some candidates inappropriately equated the resultant force to the upthrust and simply ignored the weight of the sphere. A significant number of the weaker candidates did not attempt a response.

(ii) Only the strongest candidates explained that the drag force acting on the sphere would increase as the speed of the sphere increases. This increase in drag force causes a decrease in the resultant force because the upthrust and weight remain the same. A significant number of the candidates correctly stated that the acceleration would decrease, but without providing a supporting explanation. In general, when questions use the command words 'state and explain', it is essential that an explanation is given as well as a final statement.

Question 3

(a) The principle of conservation of momentum was recalled correctly by the stronger candidates. Candidates needed to refer to the <u>total</u> momentum remaining constant. A significant number did not include the condition that there must be no resultant external force acting on the system.

(b) (i) Some candidates determined angle θ by resolving the momentum of fragment C into two perpendicular components and then equating these components with the momenta of the other fragments. Others used a momentum vector triangle to find the angle θ. A significant number of candidates who attempted to use the latter method made the mistake of using a velocity vector triangle instead of a momentum vector triangle.

(ii) Different methods of calculation were possible. Some candidates determined the speed by resolving the momentum of fragment C into two perpendicular components and then equating one of these components with the momentum of a different fragment. Other candidates used a momentum vector triangle and Pythagoras' theorem to determine the speed. The weaker candidates found this part of the question very challenging.

(c) (i) Most candidates successfully showed how to calculate the total chemical energy in the firework.

(ii) The symbol formula for kinetic energy was usually recalled correctly. Most candidates realised that they needed to equate the total chemical energy in the firework to the total kinetic energy of the three fragments. Weaker candidates were sometimes unable to determine an accurate value of the total kinetic energy. A significant number of candidates did not attempt a response.

Question 4

(a) Most candidates found it difficult to state what is meant by the frequency of a progressive wave. Many responses referred to 'per second' instead of 'per unit time'. This was inappropriate because quantities are described in terms of other quantities and not in terms of units.

(b) (i) Although the stronger candidates found it straightforward to calculate the sound wave frequency, many candidates found it difficult to undertake the first step of determining the correct time period. A common mistake was to make a power-of-ten error when converting the units of the time period into seconds.

(ii) Generally, this question was well answered. Some candidates either misread the amplitude from the screen of the CRO or incorrectly converted the amplitude from centimetres to volts.

(c) The majority of the candidates realised that they needed to sketch a waveform that has a reduced amplitude. A common misconception was that decreasing the intensity to a quarter of the original intensity would cause the amplitude to reduce to a quarter of the original amplitude. Only the stronger candidates were able to sketch a trace showing the correct amplitude. Some sketches wrongly showed a variation in the period, instead of the correct unchanged period, because the candidates had not sketched the new trace carefully enough.

(d) (i) Usually a correct reference was made to two or more overlapping waves. Only a small number of candidates clearly stated that the resultant displacement is the sum of the individual displacements of the waves (at a point). Some responses inappropriately described the addition of amplitudes instead of displacements. A significant number of candidates did not attempt a response.

(ii) Candidates found it difficult to determine the wavelength from the number of nodes and antinodes passed through by the microphone. A common misconception is that the distance between a node and an adjacent antinode is equal to one half of a wavelength. A significant number of candidates did not attempt a response.

(iii) Most candidates were able to recall the appropriate symbol equation and then use this to calculate the answer. Often the calculation included an incorrect starting value for the frequency or wavelength but full credit could be awarded here through the principle of error carried forward.

Question 5

(a) Candidates would benefit from more practice at drawing circuit diagrams and better knowledge of circuit symbols. Only a small proportion of the diagrams showed the correct circuit symbols for the heater and the light-dependent resistor. Candidates need to be able to draw and interpret circuit diagrams containing the circuit symbols shown in the syllabus.

(b) (i) Those candidates that were able to recall the correct symbol equation usually went on to calculate the correct numerical answer.

(ii) This question was usually answered correctly.

(c) (i) Most candidates were able to explain that the new wire would have a larger cross-sectional area, causing the resistance of the new wire to be less than that of the original wire. Weaker candidates sometimes gave an incorrect explanation or no explanation at all.

(ii) Many explanations were incorrect or incomplete. Stronger candidates were able to explain that the new wire would decrease the total resistance in the circuit so that there would be an increase in the current. Only the strongest candidates realised that this increase in current would cause the new voltmeter reading to be less than 4.8 V.

Question 6

(a) The Young modulus was usually defined correctly.

(b) (i) Most answers were correct.

(ii) The general equation for stress was usually recalled correctly, although sometimes the units of the cross-sectional area of the wire were incorrectly converted from mm^2 to m^2.

The general equation for strain was well known, although sometimes an error was made in determining the extension from the graph.

Question 7

(a) The stronger candidates were able to recall the charges of the quarks and antiquarks. A significant number of candidates gave an incorrect value for the charge of the charm quark. Many candidates correctly understood that an antiquark has the opposite charge to its respective quark.

(b) (i) Generally, this question was well answered. The most common correct answer was udd. A small proportion of candidates correctly stated cdd.

(ii) A significant number of the candidates did not realise that a meson consists of one quark and one antiquark.

(c) (i) Most responses were correct.

(ii) Most candidates were able to correctly state the name of another particle in the lepton group.

PHYSICS

Paper 9702/31
Advanced Practical Skills 31

Key messages

- If a raw value is out of trend to that expected, candidates should be encouraged to check the readings again with the equipment provided in the early stages of data collection.
- In the table work, the number of significant figures in the calculated quantity should relate to the number of significant figures in the raw data with the least number of significant figures. Each calculated quantity should be checked row by row. It is unnecessary, and often incorrect, to force the number of significant figures to be constant down a column of calculated values.
- In the graphical work, candidates should be able to read off any points to the nearest half a small square. In particular, candidates should check carefully the read-offs of points used in the gradient calculation and when determining the *y*-intercept.
- When justifying a number of significant figures in a calculated quantity, candidates should relate the number of significant figures in the quantity to the raw readings used in the calculation. Candidates should not use the phrase 'raw readings' without explaining what those readings are, or attempt to use intermediate calculated quantities to justify the number of significant figures.
- To be successful answering **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. General points such as 'measurements were difficult' or 'use more precise measuring instruments' will not usually gain credit without further detail.

General comments

Centres did not generally 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 additional equipment should be available to the candidates. In some cases this may disadvantage candidates.

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

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

Comments on specific questions

Question 1

(a) Many candidates gave a value of S_1 in the required range and with a unit, and also measured the length S_2. Some candidates omitted the unit or gave m as the unit when the value suggested that the correct unit was actually cm.

(b) (i) Many candidates set up the apparatus correctly so that x was approximately 75 cm and arranged the metre rule to be parallel to the bench. Candidates used a 30 cm ruler to measure L_1 and L_2. The ruler has a precision of 1 mm so raw readings should be recorded to the nearest mm. Many candidates gave the raw values of L_1 and L_2 to the nearest mm and gave the unit. Some candidates omitted units, or gave raw values only to the nearest cm.

(ii) Many candidates were able to calculate the values of e_2 and e_1 correctly where $e_2 > e_1$. Some candidates recorded values where $e_2 < e_1$.

(c) Many candidates were able to collect five sets of values of x, L_1 and L_2 without assistance from the Supervisor, and showed a correct trend in their values. A minority of candidates took a set of results with the wrong trend. Some candidates looked at the trend in their values as they recorded the values. This 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 a general trend and repeat these readings as they experiment to double-check. Some candidates did not measure x from the correct end of the rule.

Many candidates chose too small a range of x over which to conduct the experiment and so the values ended up too close together. It is expected that candidates consider the whole range of possible values of x that can be achieved with the apparatus, and aim to use as wide a range as possible.

Many candidates were awarded credit for the column headings, 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. The e_2 / e_1 column was the most challenging. There should not have been a unit given for this column. Some candidates incorrectly gave the unit for e_2 / e_1 as cm. Some candidates wrote the units in the body of the table rather than in the column heading.

Most candidates calculated and recorded their values of e_2 / e_1 correctly. A small number of candidates rounded their final answers incorrectly.

(d) (i) Most candidates gained credit for drawing appropriate axes, with labels and sensible scales. Compressed scales (in either the x or y direction) were often seen and could not be awarded credit. There were some cases of awkward scales (e.g. based on 3, 6 or having 15 squares equivalent to 1). Credit cannot be awarded for this type of scale, and these candidates often lose further credit later for incorrect read-offs when calculating the gradient or the y-intercept of the line. Some candidates created non-linear scales e.g. 0.8, 0.9, 1.0, 1.2. A small number of candidates chose scales which meant that one or more points were off the graph grid.

Many candidates gained credit for plotting their tabulated readings correctly to within half a small square. If a point seems anomalous, candidates should repeat the measurement to check for an error in recording the values. If the candidate decides that such a point should be ignored when drawing 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 anomalous points, so candidates should be reminded that they do not need to identify an anomalous point if they do not think they have one.

Many candidates plotted points carefully with dots less than or equal to half a small square in diameter. Some points were drawn as dots with a diameter greater than half a small square, and these points could be improved by using a finer pencil.

The majority of the candidates were able to collect a set of data that was awarded credit for quality.

(ii) Stronger candidates were able to draw carefully considered lines of best fit, but others did not balance the distribution of points along the length of the line. Some candidates joined the first and last points on the graph regardless of the distribution of the other points or forced the line through the origin. 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 (candidates used too small a ruler), a double line drawn (broken pencil tip) 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) Candidates need to use a large triangle to calculate the gradient, use correct read-offs and substitute into a correct expression. Weaker candidates often used too small a triangle (the hypotenuse should be greater than half the length of the line drawn) and there were many instances of incorrect read-offs. Some candidates did not draw a triangle and instead attempted to use points from the table to determine the gradient.

Some candidates were able to correctly read off the y-intercept at $x = 0$ directly from the graph, but others incorrectly read off the y-intercept when there was a false origin (i.e. not $x = 0$). There were many instances of incorrect read-offs substituted into $y = mx + c$.

(e) Many candidates recognised that P was equal to the gradient and Q was equal to the negative value of the intercept, and the values were not written as fractions or given to only one significant figure. Some candidates did not recognise that the sign of Q needed to be changed.

Stronger candidates recorded values with consistent units for P (cm^{-1}) and Q (no unit). Weaker candidates stated incorrect units using cm or omitted the units altogether.

Question 2

(a) Many candidates correctly stated a value of a to the nearest mm in the required range and provided a correct unit. Some candidates gave readings to the nearest cm, or did not give the unit.

(b) Many candidates correctly stated a value of t in the required range and added the unit, s. Some candidates did not time 10 oscillations or chose to divide their measured value by 10 giving a value outside the required range.

Many candidates repeated their experiment and recorded several values of t. Some candidates only took the measurement once and only recorded one value of t.

(c) (i) Many candidates correctly adjusted the length of the string in the split cork, recording a value for l in range with a correct unit. Some candidates did not adjust the apparatus to bring l into the required range or did not give the unit. Many candidates correctly calculated the value of $(l - a)$.

(ii) Most candidates are familiar with the equation for calculating percentage uncertainty. Some candidates estimated $\Delta(l - a)$ in the required range. Some candidates made too small an estimate of the absolute uncertainty in the value of $(l - a)$, often incorrectly giving the precision of the rule 0.1 cm which does not take into account the inherent difficulty of making the measurement.

Some candidates repeated their readings and correctly gave the uncertainty in $(l - a)$ as half the range in several values of $(l - a)$, but some weaker candidates did not halve the range. Some candidates needed to approach this by considering the whole quantity $(l - a)$ rather than attempting to combine uncertainties in l and a.

(d) Nearly all candidates correctly recorded second values of a, t and l.

Many candidates correctly recorded values of $(l - a)$ which showed an increase in the second value of $(l - a)$ compared to the first value of $(l - a)$. For some candidates the second $(l - a)$ showed the wrong trend with a decrease, suggesting that the instructions had not been followed correctly.

(e) (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.

(ii) Stronger candidates correctly justified the number of significant figures they had given for the value of k with reference to the number of significant figures used in a and $(l - a)$. Many candidates gave reference to a only or just 'raw readings', 'measured values' or 'values in calculation' without stating what these values were.

(f) Stronger candidates read the question carefully and correctly used the stated percentage uncertainty value given in the question i.e. 5%. Some candidates clearly showed the calculation of the percentage difference between their two values of *k*, then compared their percentage difference value to the 5% percentage uncertainty and stated a correct conclusion of whether the results supported or did not support the relationship.

Some candidates referred back to the percentage uncertainty calculated for $(l - a)$ and this was not credited. Some weaker candidates calculated the percentage difference but then referred to it as a 'percentage uncertainty'; candidates need to use the correct terms for 'percentage difference' and 'percentage uncertainty'. Another common mistake was to give a vague statement e.g. 'values were close together so supports' when a percentage difference calculation is needed.

(g) Stronger candidates were correctly able to calculate *g* using their value of *t* from **(d)**, dividing by 10 to find *T* and using the corresponding value of *C* from **(e)** to give a value in the appropriate range and with a unit. Common mistakes were to not give the unit, to give a value outside the accepted range, not dividing *t* by 10 to find *T* or to attempt to calculate *T* using an equation rather than using the value from **(d)**.

(h) (i) This experiment provided many limitations for discussion. The investigation compared the oscillation of a wooden strip with the oscillation of a pendulum. Candidates who think about the difficulties they experience in making a measurement as they are doing the experiment are best placed to discuss limitations.

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.

To gain credit for limitations concerning measurements, the quantity that was difficult to measure must be referred to along with the difficulty. For example, 'it was difficult to measure l' on its own is insufficient. Pointing out that 'it was difficult to measure l as the ruler is moving' or 'it was difficult to measure l as it was difficult to identify the centre of the bob', using the technical term 'parallax error' or giving the reason that 'the pendulum was disturbed by the ruler touching it' could gain credit.

Many candidates correctly identified that the rule was difficult to balance.

Many candidates correctly stated difficulties involved in measuring *t*, the time for 10 oscillations, due to difficulty in identifying the start or end of an oscillation. A bald statement 'it was difficult to measure *t* with a stop-watch' or reference to 'human error' or 'reaction time' did not gain credit. Suggesting that 'the period was short' or 'air conditioning affected the oscillations' or discussions linking amplitude to period did not gain credit.

(ii) Using a split cork is a valid way to hold the pendulum string to allow ease of adjustment to the length. Some candidates experienced difficulties in manipulating the split cork and may need more practice with making this type of adjustment with bosses, clamps and stands.

Candidates need to ensure that their solutions contain sufficient detail. For example, 'make the rule vertical' did not gain credit whereas 'clamping the rule' could gain credit. Many candidates correctly suggested the use of calipers to measure diameter, then halving it adding the radius to find l.

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.

PHYSICS

Paper 9702/32
Advanced Practical Skills 32

Key messages

- If a raw value is out of trend to that expected, candidates should be encouraged to check the readings again with the equipment provided in the early stages of data collection.
- In the table work, the number of significant figures in the calculated quantity should relate to the number of significant figures in the raw data with the least number of significant figures. Each calculated quantity should be checked row by row. It is unnecessary, and often incorrect, to force the number of significant figures to be constant down a column of calculated values.
- In the graphical work, candidates should be able to read off any points to the nearest half a small square. In particular, candidates should check carefully the read-offs of points used in the gradient calculation and when determining the *y*-intercept.
- When justifying a number of significant figures in a calculated quantity, candidates should relate the number of significant figures in the quantity to the raw readings used in the calculation. Candidates should not use the phrase 'raw readings' without explaining what those readings are, or attempt to use intermediate calculated quantities to justify the number of significant figures.
- To be successful answering **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. General points such as 'measurements were difficult' or 'use more precise measuring instruments' will not usually gain credit without further detail.

General comments

Centres did not generally 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 additional equipment should be available to the candidates. In some cases this may disadvantage candidates.

There are a number of questions in the paper where candidates needed to give measurements to the precision of the instrument (e.g. 30 cm ruler). Where an answer line does not include a unit, candidates are expected to provide a correct unit with the numerical answer, and they may not be awarded credit if they do not do so. Candidates should be encouraged to use sharpened pencils for their graphical work. This would avoid several difficulties in the presentation of graph work.

The majority of the candidates were able to complete both questions in the time available, and without seeking assistance from the Supervisor.

Comments on specific questions

Question 1

(a) Nearly every candidate recorded a value of x of 30 cm, though a small number of candidates omitted the unit. Most candidates recorded a value of θ in the appropriate range. Candidates could improve by recognising that the protractor provided only enabled a measurement to the nearest degree. Values of θ recorded as, for example, 75.2° were not given credit. It was also common to see values of θ greater than 90°. This was usually because the wrong scale had been read on the protractor, and the candidate had actually recorded (180° – θ), with the same error then occurring again in the values of θ in the table.

(b) Most candidates were able to record six sets of values, with a correct trend in their x and θ values. Many used correctly headed columns in their table, with most recognising that values of cos θ did not have units. A small number of candidates used their calculator in radians mode rather than degrees mode when calculating cos θ. Where candidates had used the wrong protractor scale to give values of θ greater than 90°, they usually recorded a wrong trend in θ values and hence a wrong trend in cos θ values.

Many candidates did not present their values of x to the correct precision, giving values to the nearest centimetre rather than the expected nearest millimetre. These candidates could improve by recognising that distances measured with a metre rule or a 30 cm ruler should be recorded to the nearest mm.

Many candidates did not use a wide enough range of values of x. Candidates could have improved by recognising that they should have used values of x lower than the 30 cm indicated in **(a)** rather than just using values larger than 30 cm. Candidates should try to use the smallest possible and largest possible values of the independent variable that can be achieved using the apparatus.

(c) (i) Many candidates placed regularly spaced numerical labels at least every 2 cm on the axes of their graph. Many candidates used sensible scale intervals and chose intervals that gave a generous spread of points in both directions across the grid. A minority used very awkward scales. This appeared to be with the intention of stretching out the plotting of points across the whole of the grid. It is only necessary for the points to occupy at least half of the large squares in each direction, and candidates should be discouraged from choosing awkward scales in an attempt to make better use of the grid.

The plotting of points was generally accurate, though a small minority of candidates used round dots to mark their points which were larger than 1 mm in diameter ('blobs'). Some candidates who used crosses to mark their points also used such thick lines that their points also reached further than 1 mm on the grid. Candidates should be encouraged to use sharpened pencils when plotting points to avoid this problem.

Many candidates were able to gain credit for the quality of their data. Some candidates were not awarded credit because of a wrong trend in the values of cos θ or, occasionally, because they had used θ values for the graph instead of cos θ values.

(ii) Stronger candidates were able to draw a carefully considered line of best fit with a balanced distribution of points either side of the line along the entire length. Common reasons for not awarding this mark included lines needing a rotation or a shift to get a better fit, lines that were kinked (two or more smaller lines joined up), lines that were drawn between the top and bottom point regardless of the distribution of the data and lines that were skewed so that the intercept could be read off the graph at $x = 0$.

If a point appears to be anomalous on the graph, candidates are encouraged to check their plotting first, then check their reading with the equipment available. If the candidate still has one anomalous point, they can identify this point as such by ringing it or stating the point as 'anomalous'.

Candidates should be encouraged to use a sharpened pencil when drawing their lines of best fit.

(iii) Candidates need to use a large triangle to calculate the gradient, use correct read-offs and substitute into a correct expression. Weaker candidates often used too small a triangle (the hypotenuse should be greater than half the length of the line drawn) and there were many instances of incorrect read-offs. Some candidates did not draw a triangle and instead attempted to use points from the table to determine the gradient.

Some candidates were able to correctly read off the y-intercept at $x = 0$ directly from the graph, but others incorrectly read off the y-intercept when there was a false origin (i.e. not $x = 0$). There were many instances of incorrect read-offs substituted into $y = mx + c$.

(d) Most candidates were able to transfer their gradient and intercept values correctly from **(c)(iii)** to give the values of a and b respectively. The most common response that did not gain credit for the values of a and b gave one or other of the values to only one significant figure.

Candidates found it more difficult to give units of a and b. A unit was sometimes omitted from both a and b, or a unit of degree was given as the unit of b. Another common error was to give a unit of $°\ m^{-1}$ as the unit for a. The unit used for a (cm^{-1} or m^{-1}) needed to be consistent with the unit (cm or m) that the candidate had used for their graph and/or gradient calculation in **(c)**.

(e) The candidates providing the best answers to this question were either already working in metres in the earlier parts of the question, or correctly converted a value of a in cm^{-1} to a value in m^{-1} (i.e. multiplying it by 100 and not dividing it by 100). They were then able to easily recognise that the unit of their value for S would be $N\ m^{-1}$. A frequently seen incorrect unit was $N\ m^{-3}$, or a composite unit involving degrees carried through from **(d)**.

Candidates who were not able to recognise a correct unit for S from the formula provided in the question could have arrived at a dimensionally correct unit by recalling the unit for spring constant, as S was defined as the spring constant.

Question 2

(a) (i) Many candidates were able to gain credit for the value of D_1, recording a value within the accepted range, and recording it to the nearest millimetre. A significant number of centres used 100 g masses of slightly smaller diameter than that expected, but candidates could be awarded credit if they were close to the Supervisor's value for D_1.

Almost all of the candidates calculated a correct numerical value for C, though there were some instances of incorrect units.

(ii) Many answers referred only to one of the two expected variables, M_1 and D_1. A good answer made reference to the significant figures in both M_1 and D_1 as these both need to be considered when deciding on the appropriate number of significant figures in C.

(iii) Many candidates recorded two or more values for T, with those values all to the nearest 0.01 s or the nearest 0.1 s. Some candidates then divided their average value of T by 16, the number of turns of the string on the flywheel, or by 10. In questions such as this where a single event is being timed, such division is not appropriate.

(b) (i) Almost all candidates recorded a value of D_2 that was greater than D_1.

(ii) Candidates found this question difficult, and a relatively small number of candidates were awarded credit. The strongest candidates used an appropriate absolute uncertainty of between 0.2 cm and 0.5 cm to correctly calculate the percentage uncertainty. Many candidates used unrealistically small values for the absolute uncertainty, often using 0.1 cm (i.e. the precision of the 30 cm ruler).

A small proportion of candidates using a half-range calculation from repeated values of D_2 determined the full range instead and, if this did not give an absolute uncertainty in the range 0.2 cm to 0.5 cm, were not able to gain credit.

A small number of candidates used the difference between their values of D_2 and D_1 as their value for the absolute uncertainty, suggesting they had misunderstood the question.

(iii) Many candidates were able to correctly substitute into the expression for the new value of *C*. Most worked consistently in units of kg cm^2 between this question and **(a)(i)**, and therefore substituted with consistent units. Candidates working in kg m^2 were likewise generally consistent in their use of units.

Candidates who did not gain credit were occasionally inconsistent in their units (e.g. using a value for $M_1D_1^2$ from **(a)(i)** that was in kg m^2 and values of M_2 and D_2 in kg and cm), but more often did not square one or other part of the expression.

(iv) A significant majority of candidates recorded a second value of *T* that was greater than their first value. A small number of candidates incorrectly recorded a second value of *T* that was smaller than their first, but this was not common.

(c) Many candidates were able to correctly calculate two values of *k*. Common errors for candidates who did not gain credit were to neglect to square their value of *T*, to calculate C / T^2 instead of T^2 / C or to give one or both of their values of *k* to only one significant figure.

(d) Most candidates calculated a percentage difference and followed through to correctly state whether or not their values of *k* supported the given expression. Some did not make the comparison with 15% explicit referring, for example, to their percentage difference not being within 'experimental accuracy'. Candidates should be encouraged to use terms 'greater than' or 'less than' when comparing their percentage difference to the percentage uncertainty given in the question. A few candidates used a criterion other than 15% (commonly 20%), and this was not able to gain credit.

Centres might refer to page 40 of the syllabus for this subject to identify the three requirements when answering this question. Candidates who miss out any one of the three, such as the calculation of a percentage difference between their two *k* values, are not able to gain credit.

(e) (i) Many candidates stated limitations in an incomplete way, either stating the difficulty without giving a reason, or stating a reason without identifying the quantity involved. 'Difficult to measure *D*' (without saying why) is an example of the first. 'Hard to tell when the mass hanger reached the floor' (without referring to *T*) is an example of the second.

A common mistake when attempting to address the problem of the readings not being enough to draw a valid conclusion was to miss out the reference to drawing a conclusion by writing, for example, 'not enough readings for an accurate result' or just 'not enough readings'.

Candidate responses that refer to 'reaction time' as a reason for inaccuracy in time values are unlikely to gain credit. Candidates should be encouraged to think in terms of short time intervals giving rise to large uncertainty in the recorded values or to look at how the start and end points of timing intervals can be judged.

A number of candidate responses referred to it being 'inaccurate to use a ruler to measure diameter'. Such answers were not able to gain credit. Some candidates referred to the effect of wind or air conditioning fans on their experiments. These responses did not gain credit as these effects were not considered to be significant.

(ii) Many candidates considered the collection of more data, but a common response that did not gain credit was 'take more readings and find average' (as this is a process that could have been followed during the experiment).

Responses in terms of wind shielding or switching off fans were not able to gain credit.

Some responses that were, in principle, worth credit were not expressed in enough detail for credit to be awarded. An example is: 'use a camera to record the experiment' without the inclusion of a timer or stop-watch in the video, without using a term that indicated a video recording rather than a still recording, or without including the viewing of the video 'frame by frame'.

Credit is not given for suggested improvements that could be carried out in the original experiment e.g. 'repeat readings' or 'view the ruler at right angles'.

PHYSICS

Paper 9702/33
Advanced Practical Skills 33

Key messages

- If a raw value is out of trend to that expected, candidates should be encouraged to check the readings again with the equipment provided in the early stages of data collection.
- In the table work, the number of significant figures in the calculated quantity should relate to the number of significant figures in the raw data with the least number of significant figures. Each calculated quantity should be checked row by row. It is unnecessary, and often incorrect, to force the number of significant figures to be constant down a column of calculated values.
- In the graphical work, candidates should be able to read off any points to the nearest half a small square. In particular, candidates should check carefully the read-offs of points used in the gradient calculation and when determining the *y*-intercept.
- When justifying a number of significant figures in a calculated quantity, candidates should relate the number of significant figures in the quantity to the raw readings used in the calculation. Candidates should not use the phrase ‘raw readings’ without explaining what those readings are, or attempt to use intermediate calculated quantities to justify the number of significant figures.
- To be successful answering **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. General points such as ‘measurements were difficult’ or ‘use more precise measuring instruments’ will not usually gain credit without further detail.

General comments

Centres did not generally 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 additional equipment should be available to the candidates. In some cases this may disadvantage candidates.

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

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

Comments on specific questions

Question 1

(a) Most candidates stated *L* in the appropriate range and with a correct unit. Some candidates omitted a unit. A minority of candidates wrote a length in cm and stated the unit as m.

(b) Many candidates stated their final *T* in the appropriate range and with a unit. Stronger candidates repeated their timing of 5 or more oscillations. Candidates are encouraged to time a number of oscillations (5 or more) and show evidence of having repeated this result. A few candidates left *T* as 10*T* and forgot to divide by 10. A minority of candidates calculated frequencies (1/*T*) and put this on the answer line.

(c) Most candidates were able to collect six sets of values of *L* and time with the correct trend without assistance from the Supervisor. Candidates are encouraged to check again their timing result if the trend is not what the candidate expects and/or one value appears to be out of trend with the rest.

Many candidates chose too small a range of lengths over which to conduct the experiment. Some candidates went up every 2.0 cm starting from $L = 45.0$ cm, or went downwards from 45.0 cm. Candidates are encouraged to use the lowest and highest possible values they can obtain with the apparatus supplied.

Many candidates gave both the quantity and correct unit for each heading separated by a solidus or with brackets around the unit. Candidates are encouraged to remember the unit and the separating mark between the quantity and unit which takes the form of a '/' or a bracket around the unit. Some candidates gave incorrect units such as L^2 / m or T^3 / s.

Many candidates stated their raw *L* readings to the nearest mm. Candidates are encouraged to think about the instrument provided, e.g. ruler, and consider what is the smallest possible reading, i.e. 1 mm. This means that all readings should be recorded to the nearest mm.

Stronger candidates correctly recorded their calculated values for L^2 to the same number of significant figures as (or one more than) the number in their raw *L* values. Candidates are encouraged to check each row individually, checking the number of significant figures in their calculated value L^2 relates to their raw *L* readings. Very often candidates incorrectly stated raw *L* to 2 significant figures (e.g. $L = 35$ cm) and the calculated L^2 (e.g. 1225) to 4 significant figures.

Many candidates calculated values for L^2 correctly. A minority of candidates incorrectly stated all their calculated values to one decimal place, so that the number of significant figures shown rose to 5.

(d) (i) Many candidates plotted the correct graph with labels of quantities asked for, and used easy-to-read, sensible and regular scales. Candidates are encouraged to choose scales such that their points occupy over half the graph grid in both the *x* and *y* direction. Some awkward scales arose because the candidate based their limits on the minimum and maximum values in their table and then calculated the intermediate values. Such scales are not awarded credit. If the irregular scale is in the region of the plotted points, the quality of data also cannot be judged and often other mistakes are made with read-offs.

Many points were plotted as neat crosses such that the centre was no more than half a square thick, were plotted correctly so that the position was within half a small square in both the *x* and *y* directions, and were on scales that are able to fit all the points. Sometimes 2025 was missed off the grid because the scale only went up to 2000, or the candidate plotted the point on the 2000 grid line.

(ii) Stronger candidates were able to draw a carefully considered line of best fit with a balanced distribution of points either side of the line along the entire length. Common reasons for not awarding this mark included lines needing a rotation or a shift to get a better fit, lines that were kinked (two or more smaller lines joined up), lines that were drawn between the top and bottom point regardless of the distribution of the data and lines that were skewed so that the intercept could be read off the graph at $x = 0$.

If a point appears to be anomalous on the graph, candidates are encouraged to check their plotting first, then check their reading with the equipment available. If the candidate still has one anomalous point, they can identify this point as such by ringing it or stating the point as 'anomalous'.

(iii) Candidates need to use a large triangle to calculate the gradient, use correct read-offs and substitute into a correct expression. Weaker candidates often used too small a triangle (the hypotenuse should be greater than half the length of the line drawn) and there were many instances of incorrect read-offs. Some candidates did not draw a triangle and instead attempted to use points from the table to determine the gradient.

Some candidates were able to correctly read off the y-intercept at $x = 0$ directly from the graph, but others incorrectly read off the y-intercept when there was a false origin (i.e. not $x = 0$). There were many instances of incorrect read-offs substituted into $y = mx + c$.

(e) Nearly all candidates recognised that E and F were equal to the gradient and intercept respectively. Some candidates incorrectly gave their value of E or F to only one significant figure.

Stronger candidates provided correct units, taking into consideration the units used in the experiment. Some candidates mixed up their units and a minority stated T instead of s in the units. Many weaker candidates omitted the units.

Question 2

(a) (i) Stronger candidates measured values of h and x to the nearest mm. Some candidates incorrectly stated h to 0.1 mm in an attempt to make both values three significant figures.

(ii) Most candidates calculated A correctly. Candidates are encouraged to round their answers correctly, e.g. 162.7 rounds correctly to 163 to three significant figures and 160 to two significant figures. Some weaker candidates often stated incorrectly 162 (truncated) or gave 162.0 or 160.0 as incorrect answers to four significant figures.

(iii) Many candidates correctly justified the number of significant figures they had given for the value of A with reference to the number of significant figures used in x and h. Weaker candidates often gave reference to 'raw readings', 'previous measurements' or 'values used in calculation' without detailing the individual raw quantities concerned. Some candidates gave invalid statements e.g. 'h is 2 s.f., x is 3 s.f., so I gave A to 4 s.f. as it is one more than my raw data'. Some incorrectly related to the number of decimal places in their stated raw data.

(b) (i) Many candidates stated c and d to the nearest mm and in the accepted ranges. Some candidates focused on keeping both measurements to three significant figures without considering the precision of the measuring instrument.

(ii) Some candidates made too small an estimate of the absolute uncertainty in the value of c, typically 1 mm or half the smallest division (0.5 mm), when this is an awkward reading to take. Some candidates repeated their readings and correctly gave the uncertainty in c as half the range, showing clear working. A small number of candidates incorrectly subtracted the d value from the c value to get the uncertainty. A minority calculated the percentage difference between c and d instead.

(c) (i) Most candidates stated x to the nearest mm and in the appropriate range.

(ii) Most candidates recorded second values of c and d. Many candidates correctly recorded second smaller values of c and d.

(d) Many candidates were able to calculate k for the two sets of data, showing their working clearly. Some candidates multiplied cA by 2 and forgot to also double the kx^3 too. Some incorrectly rounded their k value and others incorrectly stated their final values to only one significant figure.

(e) Stronger candidates calculated the percentage difference between their values of k, testing it against the stated 5% criterion. Some candidates omitted a percentage difference calculation, gave their own different criterion e.g. 10% or 20%, or presented invalid statements e.g. '5% is less than 20% so must be OK' or 'results did not support the relationship because the value was not equal to

5%’. Some candidates gave vague statements e.g. ‘values were close together so supports’ when a percentage difference calculation is needed.

(f) (i) Candidates need to identify problems associated with setting up and obtaining readings. They can do this by writing about the different measurements taken or by chronologically going through the experiment systematically and stating clearly each difficulty. Candidates should then try to think of solutions that address each problem identified.

Problems that were commonly given credit included ‘two sets of data were insufficient to draw a valid conclusion’, ‘card not able to swing freely’, ‘difficult to draw the lines as card suspended’ and ‘difficult to draw line as ruler was moving’.

Candidates detailing what is essentially the same problem with two reasons for it are only awarded credit once, so they should be encouraged to think of different problems. Weaker candidates often mentioned the problems without necessary detail.

(ii) Improvements that were commonly seen were ‘take more readings and plot a graph’ and ‘clamp the ruler’. A solution, like the problem, needs to be given with detail to gain credit. Candidates are encouraged to turn vague statements that have relevance into detailed responses in order to gain credit. Careful consideration is needed.

Many candidates gave invalid methods such as ‘clamp card’ or ‘hold ruler with retort stand’.

Credit is not given for suggested improvements that could be carried out in the original experiment e.g. ‘repeat readings’ or ‘view the ruler at right angles’.

PHYSICS

Paper 9702/34
Advanced Practical Skills 34

Key messages

- If a raw value is out of trend to that expected, candidates should be encouraged to check the readings again with the equipment provided in the early stages of data collection.

- In the table work, the number of significant figures in the calculated quantity should relate to the number of significant figures in the raw data with the least number of significant figures. Each calculated quantity should be checked row by row. It is unnecessary, and often incorrect, to force the number of significant figures to be constant down a column of calculated values.

- In the graphical work, candidates should be able to read off any points to the nearest half a small square. In particular, candidates should check carefully the read-offs of points used in the gradient calculation and when determining the *y*-intercept.

- When justifying a number of significant figures in a calculated quantity, candidates should relate the number of significant figures in the quantity to the raw readings used in the calculation. Candidates should not use the phrase 'raw readings' without explaining what those readings are, or attempt to use intermediate calculated quantities to justify the number of significant figures.

- To be successful answering **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. General points such as 'measurements were difficult' or 'use more precise measuring instruments' will not usually gain credit without further detail.

General comments

A small number of centres found that the plastic pipes they used for **Question 2** deformed when immersed in hot water, although candidates were still able to collect data and could gain credit for identifying this as a problem with the experiment. 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 additional equipment should be available to the candidates. In some cases this may disadvantage candidates.

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

The general standard of work carried out by the candidates was good. Where candidates scored less well, this was often due to improper presentation of data and lack of processing skills. Working was usually clear and legible, but some candidates should be reminded to draw tables carefully using ruled lines and, where possible, to record data systematically.

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) The majority of the candidates provided a value for the added mass that was in range and with an appropriate unit (e.g. g). A small number gave a value of 0 g, which was not accepted as candidates were instructed to ‘attach some of the 10 g masses…’.

Most candidates took repeated readings to determine the period *T*. Candidates should be encouraged to measure *nT* (where *n* is at least 5) and then repeat this. Candidates should make it clear in their working what the value of *n* is. Some candidates took repeated readings of *nT* but then forgot to divide by *n* when stating their final *T* value. Others did not provide a unit.

(b) The majority of the candidates successfully followed the instructions and recorded 6 sets of values of *M* and *T*. The most successful candidates presented their data sequentially and ensured that the full range of mass values available was included in their data. A significant number of candidates solely used the smaller masses (10 g to 60 g) and so did not make full use of the apparatus provided.

Column headings in the table were usually correct and included a suitable separator between the quantity and unit. Some weaker candidates did not provide a suitable unit for the M^2 and T^2 values.

When recording raw time (or *T*) values, candidates were expected to present their data using consistent precision. While many did this by recording all values to the nearest 0.1 s or all values to the nearest 0.01 s, a significant number of candidates focused on presenting their data to a consistent number of significant figures. Candidates should be aware that raw data should be recorded to the precision of the instrument used.

Most candidates recognised the need to present T^2 values to the same number of significant figures as (or one more than) the corresponding number of significant figures in their raw *t* values (or *T*). Candidates should consider each row of the table independently. It is not necessary for each T^2 value in the column to have the same number of significant figures.

The calculation of T^2 was correct in most cases. A small number of candidates gave a value that was incorrectly rounded.

(c) (i) Candidates producing successful graphs did so by choosing sensible scales that allowed the plotted points to occupy at least 4 large squares horizontally and 6 large squares vertically. Scale markings were clear, and values were usually written 1 large square apart. A significant number of candidates selected unsuitable scales, some labelling axes using fractions, or their table values (100, 400, 900 etc. for M^2) which led to non-linear scales. Others calculated the difference between their minimum and maximum table values and divided by the number of squares available on the grid leading to scales that required a calculator to determine where points should be. This should be discouraged.

Whilst the plotting of points was generally accurate, there were a significant number of candidates drawing points using large circles (‘blobs’) which could not be credited since, due to the large diameter, it was impossible to judge whether they were within half a small square of the intended value.

(ii) When drawing the straight line of best fit, many candidates produced thin lines that had an even distribution of points either side of the line along the full length. The most common reasons for lines not being credited were broken or kinked lines, often the result of using short rulers forcing the line to be drawn in two parts, and lines requiring a rotation.

Candidates should be made aware that, if they identify a point as anomalous and decide to ignore it when drawing the line, they need to indicate this by either circling the point or labelling it. Only one anomaly can be ignored.

(iii) Most candidates correctly read off two points from their line that were at least half the length of the line apart and then substituted points into the equation $\Delta y / \Delta x$ (or equivalent). A significant number of candidates incorrectly used $\Delta x / \Delta y$ or used points in their equation that were not on the line of best fit.

For the *y*-intercept, most candidates correctly substituted values into $y = mx + c$ (or equivalent) or took a correct read-off directly from the graph. Candidates should be aware that this second method is not valid if their *x*-axis has a false origin.

(d) Most candidates recognised that *a* was equal to their gradient value and *b* was equal to their *y*-intercept value. Units were often provided but weaker candidates did not always state units that were dimensionally correct.

Question 2

(a) The majority of the candidates provided a value for *L* with a unit that was within the expected range and measured to the nearest mm.

Although the room temperature T_0 was usually quoted to the nearest degree along with a correct unit, some candidates omitted units or gave an incorrect one (commonly ° rather than °C). Candidates should be reminded that the degree on its own is a unit of angle and the correct unit for Celsius temperatures is °C.

(b) (i) The value of x_1 was stated to the nearest mm by most candidates and a correct unit was usually provided.

(ii) The candidates' values of water temperature *T* was almost always higher than their value of room temperature and the value of x_2 differed from that of x_1.

(iii) Almost all candidates were able to correctly calculate $(x_1 - x_2)$.

(iv) When asked to estimate the percentage uncertainty in $(x_1 - x_2)$, successful candidates chose an absolute uncertainty in the range 0.2–0.5 cm. They then divided the absolute uncertainty by their $(x_1 - x_2)$ value before multiplying the result by 100. Most of the candidates who did not gain credit stated the resolution of the rule (0.1 cm) as their absolute uncertainty.

(c) Almost all candidates provided second values of *L*, x_1, *T* and x_2. In a very small number of cases, the second value of *L* (shorter pipe) was not smaller than the first value of *L* (longer pipe) indicating that the instructions had not been followed correctly.

(d) (i) Most candidates were able to correctly calculate two *k* values.

(ii) While some candidates successfully linked the significant figures in *k* with those in $(x_1 - x_2)$, *L* and $(T - T_0)$, a significant number referred only to 'raw data' or made a partial reference to the correct quantities.

(e) Candidates were provided with a numerical criterion to test against (20%). As such, the Examiners were looking for a correct percentage difference calculation, a comparison with 20%, and a correct conclusion linking both. Whilst some candidates were able to correctly carry out a suitable percentage difference calculation (e.g. (difference between *k* values ÷ mean *k* value) × 100), many were not. Some candidates carried out a correct calculation, but then incorrectly referred to the outcome as the percentage uncertainty (rather than the percentage difference they had calculated). A small number of candidates were not awarded credit because they chose to test against their own criterion, e.g. 10%.

(f) (i) This part of the paper provided a challenge for many candidates. Most candidates recognised that there were too few data points to draw a conclusion, but found it difficult to identify the other limitations and sources of uncertainty. Centres should encourage candidates to follow the instructions and always state the quantity being measured along with the reason for the uncertainty. Many candidates recognised limitations but did not link these to the correct quantity. For example, many stated that the rod moves but did not link this to the measurement of *x*. It is recommended that candidates write their responses beginning with the quantity affected. For example, ‘it was difficult to measure *x* because…’

It is also worth noting that where two measurements of the same type are taken (e.g. room temperature and water temperature) the candidate should make it clear which measurement they are referring to rather than just stating ‘the temperature’ as this may be crucial to whether credit is awarded. For example, there were various difficulties in measuring the water temperature accurately but there was no reason for difficulty in measuring room temperature.

(ii) Most candidates recognised the need for more data so that a graph could be plotted. Other common correct suggestions were clamping the rule and/or thermometer, using longer pipes (to increase the difference between the *x* values) and stirring the water before measuring its temperature.

Candidates should be aware that the Examiners do not look for links between responses in **(i)** and **(ii)**. As such, candidates should restate any apparatus/quantity in **(ii)** and avoid using phrases such as ‘clamp it’ assuming the Examiner knows what ‘it’ is by locating a corresponding response in **(i)**. Credit is not given for suggested improvements that could be carried out in the original experiment e.g. ‘repeat readings’ or ‘view the ruler at right angles’.

PHYSICS

Paper 9702/35
Advanced Practical Skills 35

Key messages

- If a raw value is out of trend to that expected, candidates should be encouraged to check the readings again with the equipment provided in the early stages of data collection.
- In the table work, the number of significant figures in the calculated quantity should relate to the number of significant figures in the raw data with the least number of significant figures. Each calculated quantity should be checked row by row. It is unnecessary, and often incorrect, to force the number of significant figures to be constant down a column of calculated values.
- In the graphical work, candidates should be able to read off any points to the nearest half a small square. In particular, candidates should check carefully the read-offs of points used in the gradient calculation and when determining the *y*-intercept.
- When justifying a number of significant figures in a calculated quantity, candidates should relate the number of significant figures in the quantity to the raw readings used in the calculation. Candidates should not use the phrase 'raw readings' without explaining what those readings are, or attempt to use intermediate calculated quantities to justify the number of significant figures.
- To be successful answering **Question 2**, candidates should be reminded that their identified limitations and suggestions for improvement must be focused on the particular experiment being carried out. General points such as 'measurements were difficult' or 'use more precise measuring instruments' will not usually gain credit without further detail.

General comments

Centres did not generally 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 additional equipment should be available to the candidates. In some cases this may disadvantage candidates.

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

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

Comments on specific questions

Question 1

(a) Most candidates stated I_1 to the nearest 0.1 mA, in the appropriate range and with a consistent and correct unit.

(b) Most candidates correctly stated I_2 to be smaller than I_1.

(c) Many candidates were able to collect six sets of values of *w*, I_1 and I_2 without assistance from the Supervisor and with the correct trend. Candidates are encouraged to check their results again if the trend is not what the candidate expects and/or one value is out of trend with the rest.

Many candidates chose too small a range over which to conduct the experiment. Some candidates went up every 5.0 cm, starting from w = 70.0 cm, or went downwards from 70.0 cm. Candidates are encouraged to use the lowest and highest possible values they can obtain with the apparatus supplied.

Many candidates gave both the quantity and correct unit for each heading separated by a solidus or with brackets around the unit. Candidates are encouraged to remember the unit and the separating mark between the quantity and unit which takes the form of a '/' or a bracket around the unit.

Many candidates stated their raw *w* readings to the nearest mm. Candidates are encouraged to think about the instrument provided, e.g. ruler, and ask themselves what would be the smallest possible reading, e.g. 1 mm. This means that all readings are to be recorded to the nearest mm.

Some candidates correctly recorded their calculated values for I_1I_2 to the same number of significant figures or one more than their raw I values. Candidates are encouraged to check each row individually, checking that the number of significant figures in their calculated value I_1I_2 relates to their raw I readings. Very often raw I was given to 3 significant figures and I_1I_2 stated to 5 or 6 significant figures. Candidates should use the same number of significant figures (or one more) in calculated I_1I_2 values compared with the number of significant figures used in the raw I values.

Many candidates calculated values for I_1I_2 correctly. Some candidates added or subtracted the currents instead of multiplying them. A few candidates did not calculate anything and then incorrectly plotted individual graphs. Candidates are encouraged to round their answers correctly.

(d) (i) Many candidates plotted the correct graph with labels of quantities asked for, with easy-to-read, sensible and regular scales. Candidates are encouraged to choose scales such that their plotted points occupy over half the graph grid in both the *x* and *y* direction. Reasons for not awarding credit for the graph axes include awkward scales, compressed scales and irregular scales.

Many points were plotted as neat crosses such that the centre was no more than half a square thick, were plotted correctly so that the position was within half a small square in both the *x* and *y* direction, and were on scales that are able to fit all the points.

(ii) Stronger candidates were able to draw a carefully considered line of best fit with a balanced distribution of points either side of the line along the entire length. Common reasons for not awarding this mark included lines needing a rotation or a shift to get a better fit, lines that were kinked (two or more smaller lines joined up), lines that were drawn between the top and bottom point regardless of the distribution of the data and lines that were skewed so that the intercept could be read off the graph at $x = 0$.

If a point appears to be anomalous on the graph, candidates are encouraged to check their plotting first, then check their reading with the equipment available. If the candidate still has one anomalous point, they can identify this point as such by ringing it or stating the point as 'anomalous'.

(iii) Candidates need to use a large triangle to calculate the gradient, use correct read-offs and substitute into a correct expression. Weaker candidates often used too small a triangle (the hypotenuse should be greater than half the length of the line drawn) and there were many instances of incorrect read-offs. Some candidates did not draw a triangle and instead attempted to use points from the table to determine the gradient.

Some candidates were able to correctly read off the *y*-intercept at $x = 0$ directly from the graph, but others incorrectly read off the *y*-intercept when there was a false origin (i.e. not $x = 0$). There were many instances of incorrect read-offs substituted into $y = mx + c$.

(e) Nearly all candidates recognised that *P* and *Q* were equal to the gradient and *y*-intercept respectively. Stronger candidates provided correct units, taking into consideration the units used in their experiment.

Question 2

(a) (i) Most candidates measured values of D to the nearest mm, in the appropriate range and with a consistent and correct unit.

(ii) Some candidates made too small an estimate of the absolute uncertainty in the value of D, typically 1 mm, when this is a difficult reading to take. Some candidates repeated their readings and correctly gave the uncertainty in D as half the range, showing clear working.

(b) Many candidates stated a value for T_1 in the appropriate range and with a unit. Some candidates correctly repeated their measurement using at least five oscillations.

(c) (i) Most candidates correctly stated T_2 to be smaller than T_1.

(ii) Most candidates calculated $(T_1 - T_2)$ correctly.

(d) Nearly all candidates recorded second values of L and D. Most candidates correctly recorded a larger second value of L and D.

(e) (i) Many candidates were able to calculate k for the two sets of data, showing their working clearly.

(ii) Many candidates correctly justified the number of significant figures they had given for the value of A with reference to the number of significant figures used in $(T_1 - T_2)$, D and L. Weaker candidates gave reference to ‘raw readings’, ‘previous measurements’ or ‘values used in calculation’ without detailing the individual raw quantities concerned.

(f) Stronger candidates calculated the percentage difference between their values of k, testing it against the stated 10% criterion. Some candidates omitted a percentage difference calculation, gave a different criterion, e.g. 20%, or presented invalid statements.

(g) (i) Candidates need to identify problems associated with setting up and obtaining readings. They can do this by writing about the different measurements taken or chronologically go through the experiment systematically and state clearly the difficulty. Candidates should then try to think of solutions that address each problem identified. Some candidates seem to get fixated on two problems and then cannot widen their responses beyond these. Candidates detailing what is essentially the same problem with two reasons for it are only awarded credit once, so they should be encouraged to think of different problems. Candidates would benefit from further practice here.

Problems that were commonly awarded credit included ‘two sets of data were insufficient to draw a valid conclusion’ and ‘difficult to measure D because of the curved shape of the jar’. Candidates often mentioned the problems or the reason without necessary detail e.g. ‘difficult to measure D (or L or T)’ without a reason why and ‘difficult to find the centre of the bob’ without relating this to the measurement of L.

(ii) Improvements that were commonly seen were ‘take more readings and plot a graph’ and ‘use vernier calipers’. A solution, like the problem, needs to be given with detail to gain credit. Candidates are encouraged to turn vague statements that have relevance into detailed responses in order to gain credit.

Credit is not given for suggested improvements that could have been carried out in the original experiment e.g. ‘repeat readings’ or ‘time more oscillations’ or ‘measure D across different diameters’.

PHYSICS

Paper 9702/41
A Level Structured Questions 41

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. Examiners will only consider symbol equations to be part of a definition if the symbols used are identified.

- 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 had insufficient time in which to complete the paper. There were, however, significant numbers of candidates who did not offer a response to one or more questions. If there is no response, it is never possible for credit to be awarded, so candidates should be encouraged to offer a response to every question on the paper. Even if the candidate is not confident about the answer, it is always possible that the Examiner may be able to award partial credit where there is some response.

Comments on specific questions

Question 1

(a) (i) Only a minority of candidates knew the syllabus 'bookwork' that defines gravitational field as force per unit mass. Many candidates did not give the definition of a quantity but instead answered a different question, asking what is meant by the concept of a gravitational field. As this was such a common misunderstanding of the question, the Examiners did award credit on this occasion for responses that answered the latter question. However, teachers should be aware that candidates are expected to know the syllabus definition that gravitational field is a vector quantity, given by the force per unit mass on an object.

(ii) The comments for **(a)(i)** are also relevant here for the definition of electric field. Candidates are expected to know the syllabus definition that electric field is force per unit positive charge.

(iii) There were many correct similarities and differences stated here. Some candidates gave responses that were correct for forces or fields rather than potentials, such as "both are inversely proportional to distance squared" or "one is attractive and the other is repulsive".

(b) (i) This proof proved to be challenging for many candidates. A significant number of candidates started with the definition of electric field strength as F / Q which is correct, but they needed to extend it to the field due to a point charge. Some candidates were attempted to equate the two field strengths, when they have different dimensions so cannot be equated.

(ii) Candidates who did not reach the required expression in **(b)(i)** were unable to show the numerical value for α here. They did not know the combination of constants that was represented by α. It should be noted that full substitution is required in 'show that' calculations, including all constants. Here it was necessary to see the numerical values for ε_0 and G being used to determine the value of α.

(c) (i) Many candidates used the expression stated in **(b)(i)** to calculate the electric field strength at the surface of the Earth. However, some then gave their answer to two significant figures when the data were given to three significant figures. The requirement for a unit also proved challenging to many candidates. Weaker candidates often tried to answer this by starting once again from first principles, only to find that they did not have enough information to do this.

(ii) There were many correct answers here comparing the directions of the two fields. Some candidates did not realise the significance of the information at the start of **(c)** that the charge carried by the Earth is negative. Some gave the general case and said the direction of the electric field could be towards or away from the surface of the Earth. Some candidates said the directions were opposite, presumably assuming that the charge of the Earth was positive.

Question 2

(a) This question proved to be challenging. Many candidates did not refer to the components of the tension as required. Many referred to components of the weight or thought that the centripetal force was a third force acting, rather than the resultant of the tension and weight. A small number of candidates seemed to think the sphere was oscillating from side to side like a pendulum, rather than describing horizontal circles. The failure to realise the components of the tension at this stage often led to incorrect approaches to the numerical questions later on.

(b) (i) Most candidates were able to use basic trigonometry to show the value of the radius of the circle.

(ii) This 'show that' question proved to be challenging as candidates found it difficult to resolve forces correctly here. Some candidates did not show what they were doing clearly enough, with a numerical value for the weight appearing without the evidence that it was from the multiplication of mass $\times$ gravitational field strength.

(iii) Candidates also found this question difficult. Most candidates tried to apply $k = F / e$ but often did so incorrectly. The extra extension (10.8 cm – 8.5 cm) was not always used and the extra force (3.2 N – (0.29 $\times$ 9.81) N) was rarely used.

(c) (i) Many candidates tried to apply the equations of circular motion here. Only the strongest candidates used $F = ma$ and the horizontal component of the tension as F as necessary.

(ii) Candidates were more successful here, with many gaining credit. The use of circular motion equations, which many had unsuccessfully tried in **(c)(i)**, was necessary here.

Question 3

(a) Candidates found it difficult to demonstrate a good understanding of thermal equilibrium. The idea that thermal energy would still transfer between the two objects, but that the resultant or net transfer was zero, was often not known. This was seen through the omission of the word 'net'. In addition, some candidates did not clarify that the relevant energy was thermal energy.

(b) Candidates needed to refer to the information provided in the graphs. It was common for candidates to refer to the linearity of the relationship, or lack of linearity. Some candidates, however, stated that the relationship between density and temperature for mercury was proportional, which is incorrect. A small number of candidates correctly referred to state changes, but the evaporation of water was not appropriate here.

(c) (i) The majority of candidates correctly stated the boiling temperature of the liquid.

(ii) This calculation proved to be challenging. Many candidates ignored the energy required to raise the temperature of the beaker. A large number of candidates who included the beaker began with the incorrect statement that the energy gained by the beaker was equal to the energy gained by the water. Some candidates calculated the change in temperature correctly as 55 °C but then converted this change into kelvin as if it were a Celsius temperature. This is incorrect physics.

(d) The general shape of the line was correct for most candidates here. Some details were often incorrect, including the approximate gradient of the first part of the line and starting the line from the same temperature.

Question 4

(a) The basic assumptions of the kinetic theory of gases are generally well known. Candidates sometimes referred to the volume of the gas rather than the volume of the particles. Others incorrectly referred to the volume of a single particle.

(b) (i) Most candidates started with the correct equation here. Some candidates then did not go on to use the conditions given in the question which included a pressure of $2p$ when the volume was V. Some candidates did not rearrange the starting equation to make T the subject when they had been asked to determine an expression for T.

(ii) There were many correct responses here, although the line drawn to join Z to X was often a straight line rather than a curve. Some candidates drew more than two dots and some did not add the lines. The lines were needed to show the variation of the pressure with the volume as required by the question.

(iii) Only the strongest candidates correctly completed this table in full. Many candidates found it difficult to correctly apply the first law of thermodynamics for the three changes. They often did not know where to begin on the table, which was by filling in the information for changes already given to them. The information for the remaining changes was deduced from these. Finally, some candidates used letters that were not appropriate, for example a Q to denote thermal energy and a single letter p, which was not an energy.

Question 5

(a) (i) The majority of the candidates knew that the component was a diode and correctly drew the symbol. There were a few other components drawn, such as cells. There was some confusion between a NOT gate (which is not a symbol required by the syllabus) and a diode.

(ii) Whilst most candidates knew that the purpose of the capacitor was to smooth the output voltage, some were under the impression that the capacitor would decrease the output voltage. This may have come from thinking about the exponential curve seen for the discharge of a capacitor. In fact the capacitor increases the average V_{OUT}.

(b) (i) Most candidates correctly determined the frequency of the supply.

(ii) Many candidates were able to use the exponential formula to show the value of the time constant. Some used the total time elapsed (0.04 s) rather than the time interval (0.02 s). Some attempted to use $\tau = RC$, but not enough information was known at this stage for this equation to be helpful.

(iii) There were many correct answers for the capacitance.

(c) Many candidates realised that the output voltage would now be constant. Candidates found it more difficult to explain that this was due to the magnitudes of the positive and negative parts of the input voltage being equal.

Question 6

(a) Candidates generally knew what is meant by a magnetic field. The most common mistake was to refer to the force acting on a charged particle, rather than a moving charged particle. When candidates referred to more than one object that the force was exerted upon, they all needed to be correct.

(b) Most candidates gained credit for drawing field lines that were concentric circles. Most candidates also gained credit for the direction of the field lines. However, for some candidates, the separation of the field lines did not convincingly increase with distance from the wire and for some the separation was definitely intended to be constant.

(c) (i) Most candidates correctly calculated the force per unit length.

(ii) Many correct directions were stated here. However, many candidates did not either remember that currents in opposite directions would cause a repelling force or could use Fleming's left-hand rule to deduce this from first principles.

(iii) Many candidates determined the correct magnitude of current in wire P. However, a large number did not explain their reasoning or did not do so fully enough.

Question 7

(a) The definition of de Broglie wavelength is given in the syllabus. Many candidates quoted this correctly but the word 'moving' was frequently missing. Another common mistake was for candidates to state a formula, which is not correct in this instance.

(b) (i) The majority of candidates correctly stated electron diffraction here. Some candidates referred to the photoelectric effect, the production of X-rays or other phenomena showing they were not familiar with the diffraction of electrons.

(ii) The question asked candidates what could be concluded from the pattern in Fig. 7.2. To be awarded full credit, candidates had to explain that the pattern was indicating diffraction and go from there to explaining that therefore the electrons must be behaving as waves. Candidates often were given credit for stating that electrons were behaving as waves but very rarely explained the pattern.

(c) (i) A common mistake here was to forget the central dark circle which will always be there no matter what the speed of the electrons.

(ii) Candidates generally realised that an increase in p.d. would lead to a greater electron momentum and hence a shorter de Broglie wavelength, but they did not always explain why that changed the pattern.

Question 8

(a) (i) Most candidates correctly showed how to reach the required value of the specific acoustic impedance.

(ii) The majority of candidates were able to complete the table, but not all candidates gave values to three significant figures as required by the question.

(b) (i) Most candidates applied the correct equation here and calculated the correct answer. However, there were some issues with rounding and quoting the final answer to the correct number of significant figures.

(ii) The majority of candidates reached the correct value.

(c) Candidates demonstrated good knowledge of the purpose of the gel used in ultrasound scanning. They knew this would increase the transmission, but some candidates were imprecise in their descriptions, stating that 'most' of the ultrasound was transmitted rather than 'almost all' of the ultrasound. 'Most' can be very much less that almost all of it.

Question 9

(a) Many candidates tried to define half-life in terms of the number of nuclei present. The problem with this definition is that, in many cases, the number of nuclei present does not change. If this is the way that candidates wish to define half-life, then they need to use the words 'radioactive' or 'undecayed' when referring to the nuclei so that the nuclei of the decay product are not part of the definition. A much simpler definition is the time taken for the activity of a sample to halve.

(b) There were many correct lines that were accurately drawn here. However, there were also many candidates that drew the decay curve for carbon-11 rather than the growth curve for boron-11.

(c) (i) Very few candidates realised the key point here that the probability of decay of a nucleus per unit time is constant, which is why the decay is random.

(ii) Many candidates did not realise that the measured count rate from a sample is always less that its activity. The reasons given by those candidates who correctly stated the count rate would be less than the activity were not always sufficiently detailed to gain credit.

Question 10

(a) There were many correct responses here. Some candidates mixed up Hubble's law with Wien's displacement law. The idea of velocity being proportional to distance was often known, but many candidates neglected to talk about the velocity being that of an object emitting light (i.e. a galaxy) and that the velocity was recessional. They also sometimes omitted the fact that the distance was from the observer.

(b) Most candidates calculated the correct value for the radiant flux intensity here. Some weaker candidates started from an incorrect formula, and some forgot to square the distance.

(c) (i) Candidates generally realised that the galaxy was moving away from the Earth, but did not always say that the redshift or Doppler effect was causing the increase in the wavelength of the light received on the Earth.

(ii) There were many correct answers to this two-step calculation. However, a large number of candidates used an incorrect wavelength in the denominator of the redshift equation. Some candidates used the value of the speed of light instead of the recessional speed in the Hubble equation.

PHYSICS

Paper 9702/42
A Level Structured Questions 42

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. Examiners will only consider symbol equations to be part of a definition if the symbols used are identified.

- 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 had insufficient time in which to complete the paper. There were, however, significant numbers of candidates who did not offer a response to one or more questions. If there is no response, it is never possible for credit to be awarded, so candidates should be encouraged to offer a response to every question on the paper. Even if the candidate is not confident about the answer, it is always possible that the Examiner may be able to award partial credit where there is some response.

Comments on specific questions

Question 1

(a) This question was generally well answered, with most candidates able to give a correct statement of Newton's law of gravitation.

(b) This question was also well answered. Most candidates were able to equate the expression for gravitational force, from Newton's law of gravitation, with an expression for centripetal force as the starting point. The substitution for T and completion of the algebra to obtain the given equation was also done correctly by many candidates.

(c) Candidates who appreciated that the period of a geostationary orbit is 24 hours and that the height above the surface is equal to the radius of the orbit minus the radius of the Earth were able to be awarded at least partial credit, and full credit for the correct answer was common. Many of the weaker candidates started incorrectly by inserting the radius of the Earth into the given equation to find the period for a hypothetical orbit at the level of the Earth's surface.

(d) (i) The more able candidates had little difficulty with this question, but a significant number of the weaker candidates did not know the difference between angular speed and linear speed.

(ii) Candidates needed to read this question carefully. The question asked about the orbit of the satellite that is not in geostationary orbit, so candidates who simply listed properties of a geostationary orbit did not answer the question and could not be awarded credit. Some of the weaker candidates discussed different periods or orbital radius, despite it being stated in the question that these properties of the orbit were the same as that of the geostationary satellite. Most candidates who read and answered the question carefully gave responses that were awarded credit.

Question 2

(a) (i) Most candidates were able to state that an ideal gas is one that obeys the relationship $pV \propto T$ for all values of p, V and T. Fewer went on to clarify that T is the thermodynamic temperature. Some weaker candidates did give the correct relationship, but then contradicted it by stating that it only applies under certain conditions (such as when T is constant or under standard conditions). A significant minority of candidates confused the definition of an ideal gas with the basic assumptions of the kinetic theory.

(ii) The syllabus requires candidates to know the exact value of the conversion between temperatures in kelvin and temperatures in degrees Celsius, and so credit was awarded to candidates who gave the value of absolute zero as –273.15 °C.

(b) (i) The more able candidates had little difficulty with this question, and were generally awarded full credit for a correct answer after identifying the correct starting equation and performing the calculation to the three significant figure precision warranted by the data in the question. Many of the weaker candidates used the wrong starting equation and calculated a number of moles, and appeared to think that this was what the question required. Calculation of a number of moles, with no attempt at a conversion to obtain the number of molecules, could not be awarded credit.

(ii) Most candidates realised that the answer to this question required the division of the mass of the gas by their answer to **(b)(i)**. It was possible to obtain credit here from an incorrect answer to **(b)(i)** through the standard error carried forward principle. Some candidates did not appreciate that the data still demands a three significant figure answer.

This is a question where candidates should pause to think about the plausibility of their answer. It was not uncommon to see incorrect answers giving the mass of a molecule of the order of 10^{26} kg. Candidates who carried out a quick check of the sense of their answer would have realised that a mistake must have been made in such a calculation.

(iii) There were two possible methods to answer this question, one of which used the mass of a molecule and the other of which used the mass of the gas. Confusion between the two was very common, and only the more able candidates were able to arrive at the correct final answer.

(c) Most candidates were able to be awarded at least partial credit, for a line between (0, 0) and (500, v). Some lines went well beyond the 500 K maximum temperature and could not be awarded credit. Credit for deducing the correct direction of curvature was generally only obtained by the stronger candidates.

Question 3

(a) Most candidates knew that the first law of thermodynamics involves a relationship between change in internal energy, the transfer of thermal energy and the work done. Only a minority of candidates could give a fully correct statement of the law, with the directions of transfer clearly and consistently stated for all three quantities. A common confusion was between the energy possessed by the system and the transfers that are the means by which this quantity can be changed. Candidates should appreciate that thermal energy and work are not energies that are possessed by the system (and so they cannot 'change') but are means of energy transfer that result in changes to the internal energy of the system.

(b) (i) There were several misconceptions, including in some cases a lack of appreciation that the internal energy of the gas is proportional to the product pV and that its direction of change can be determined directly from the pV graph.

(ii) Candidates found this question difficult. It required candidates to apply the first law of thermodynamics to the complete cycle and to discuss the overall energy changes involved. Some candidates gained credit for observing that the overall change in internal energy over a full cycle is zero, but those that also went on to consider the transfer of thermal energy and the doing of work over the full cycle often incorrectly stated that these terms were zero as well. Only the strongest candidates appreciated that the work done by the gas in stage CD is greater than the work done on the gas in stage AB and that, over a complete cycle, the gas therefore does work that must come from a net input of thermal energy.

Question 4

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

(ii) This question was also generally well answered.

(iii) Most candidates correctly recalled the equation linking maximum acceleration and amplitude, although some gave the general equation for simple harmonic motion and were not awarded credit for the equation until it was clear that the maximum value of displacement was the value substituted. A common error was to neglect the power of ten conversion from cm to m, and to obtain an answer of $320\,\text{m}\,\text{s}^{-2}$.

(b) Many closed loops were seen from weaker candidates who were confusing acceleration with velocity. Most of the more able candidates appreciated that the acceleration–displacement graph for simple harmonic motion is a straight line through the origin with negative gradient. Some candidates did not take sufficient care to ensure that the line reached the maximum values of a and x with the required half-square accuracy. Many other candidates did not appreciate that the line had to end at those points, and not continue past the maximum values.

(c) Of the three extended writing questions in this paper, this question was answered the most successfully. Candidates were asked to describe the interchange of kinetic and potential energy of the oscillations. Credit was available for stating where in the oscillation each form of energy is a maximum and when it is zero, and that at any stage in the oscillation the sum of the kinetic and potential energies remains constant. A common misconception among weaker candidates was to confuse the potential energy of the oscillations with gravitational or elastic potential energy individually (not appreciating that the potential energy of the oscillations is the sum of the two). Responses to the effect that the potential energy is maximum at the top of the oscillations and minimum at the bottom could not be awarded credit. Correct use of technical terms was difficult for some candidates, with the terms amplitude and displacement being commonly conflated.

Question 5

(a) Both **(i)** and **(ii)** were generally well answered by most candidates who read the question. Expressions for Q_A and E_A were asked for in terms of C and V, and credit was only awarded for correct responses given in terms of these symbols.

(b) (i) Many candidates found this question difficult. Some did not discuss charge transfer at all, but instead wrote about energy. For credit, candidates needed to explain that some (but not all) of the charge on capacitor A moves across to capacitor B, as a result of an initial difference in the p.d. across the two capacitors, and that this process stops when the p.d.s across them become equal. The most common incorrect answer was that capacitor A fully discharges (often with no discussion of where the charge goes).

(ii) Many candidates found it difficult to give a coherent answer to this question, with responses often containing unexplained algebra. In questions asking candidates to prove an equation, explaining their reasoning, it is important that they understand the need to make clear the principles of physics on which the answer is based.

In this derivation, there were two possible approaches that candidates could take. For each approach, there were two principles of physics that needed to be made clear. In the first method, which was based on considering the two capacitors separately, it had to be clear that the final p.d.s across the two capacitors are equal, and that the sum of the charges on the two of them is still equal to CV. In the second method, which was based on considering the pair of capacitors as a single combined capacitor, it had to be clear that the <u>total</u> capacitance is $4C$ and that the <u>total</u> charge is still equal to CV. Once the points of physics were clear, access was then available to credit for completing the algebra correctly to arrive at the required equation.

(iii) This was a demanding question, aimed at discriminating between the higher-ability candidates, and many of them did successfully arrive at the correct answer. Many other candidates were able to obtain partial credit, either for correctly identifying the final energy as $⅛CV^2$ or for the method of subtracting a plausible final energy from $½CV^2$.

Question 6

(a) (i) This question was generally well answered, with most candidates knowing the definition of magnetic flux. A small number of candidates spoilt what would otherwise have been a creditworthy response by adding a second, contradictory, definition. Some gave the definition of flux density, and others defined magnetic flux as a number of lines (which would make it a dimensionless quantity).

(ii) This question was generally well answered, although there were some candidates who, whilst successfully calculating the numerical value, did not know the unit of magnetic flux. It was also common for weaker candidates here to consider that one significant figure was sufficient in the answer.

(b) This question was generally well answered, with full credit being common.

(c) This question is a good example of the need to answer the question that was asked, and not attempt to reproduce the mark scheme for a question from a previous paper. This question did not ask candidates to explain why there is an induced current, and it did not ask for a statement of Lenz's law. The question asked candidates to use Lenz's law to determine the direction of the current in the disc.

The key to answering the question was to appreciate that the current in the disc, being perpendicular to the external magnetic field, causes a force to act on the disc. The point where Lenz's law is applied is to determine that the direction of this force must be to oppose the rotation of the disc (which is the change that leads to the induced e.m.f.). Once the direction of the force on the disc is known, Fleming's left-hand rule can then be used to determine the current direction.

Many responses were very muddled, with some candidates confusing the external magnetic field with the field created by the induced current, others having two currents in the disc (one in each direction), others having currents opposing fields as if two completely different quantities can be compared and others having e.m.f.s or currents (rather than a force) opposing motion.

As a suggestion of general guidance, when candidates are asked to apply Lenz's law, they should stop to consider: what is the change that is causing the induced e.m.f.? Is it a changing field? It is it a changing current? Is it motion through a field? When the nature of the change has been determined, it is then a simple step to apply Lenz's law to determine how that change must be opposed. If an increasing field, then another field set up in the opposite direction would oppose the change. If a decreasing field, then another field set up in the same direction would oppose the change. If movement through the field, then a force would oppose the motion. Then, to create the response around that analysis, candidates should address the particular scenario presented in the question and not resort to attempting to replicate irrelevant learnt answers.

Question 7

(a) (i) Most candidates were able to identify the circuit as producing full-wave rectification.

(ii) A variety of different responses was seen, but most candidates were able to deduce that all three additional diodes must point in the same direction as the one printed in the diagram.

(iii) More candidates responded correctly than incorrectly, although a significant number of candidates offered no response to this question.

(b) (i) Many correct graphs were seen, with the award of full credit being common among the stronger candidates. Many of the weaker candidates drew graphs that showed no rectification.

(ii) The difference between the rectified voltage–time graph and the power–time graph is not understood by many candidates. Many candidates drew graphs that had the same shape as the answer to **(b)(i)**. Candidates cannot appreciate the reason why the mean power is half the peak power for sinusoidal a.c. without knowing the correct shape for the power–time graph.

(iii) Candidates found this a very challenging question. Whilst many candidates did correctly conclude that the r.m.s. voltages are equal, most found it difficult to adequately articulate the reason why this is the case.

Question 8

(a) This question required accurate use of the technical terms energy levels, difference in energy levels, photon energy and radiation frequency. Many responses could not be awarded credit because these terms were not used correctly, often conflating them as all meaning the same thing. Examiners were looking for clear discussion of emitted photon energy as being equal to the difference in energy levels and having a corresponding frequency. Many responses did not have any discussion of photon energy at all, and simply attempted to relate frequency to the energy levels.

(b) Many candidates did not appear to understand what was being asked in this question, and for both **(i)** and **(ii)** drew lines on Fig. 8.1 to represent the transitions rather than the spectral lines on Fig. 8.2 that were asked for.

(c) Most candidates knew the photon energy equation as the starting point, and many of the more able candidates were able to go on to deduce the correct expression.

Question 9

(a) The definition of mass defect appears to be not as well known as most definitions, and many candidates did not give a correct answer. Many candidates tried to suggest that it is an energy, and others described it as a change in mass during a nuclear process. Correct use of technical terms is important, and many responses conflated nucleus, nucleons and neutrons by using them as synonymous terms.

(b) (i) Weaker candidates found it difficult to identify particle X as a neutron, but the stronger candidates generally had little difficulty with this.

(ii) Many candidates answered this question well, and full credit was common. As ever with 'show that' questions, candidates should be advised that full credit requires full substitution of all the working. There were some careless errors in transcribing the mass data that resulted in candidates not being awarded credit, and other candidates omitted to show the multiplication by the value of u or the value of c^2.

(c) (i) This was a challenging question. It was not possible to answer just by recalling an equation and plugging numbers into it. The first step required was to appreciate that the luminosity gives the energy released per unit time and the previous question gives the energy released per nucleus. Between these two, the number of nuclei of helium produced per unit time can be determined. The second step was to determine the mass of a helium nucleus in kg. The two steps can then be put together to determine the mass of helium produced per unit time. Weaker candidates found it difficult to know where to start, often just trying to use the Stefan–Boltzmann law inappropriately because the word 'luminosity' was in the question. A significant proportion of the more able candidates gave fully correct answers and could be awarded full credit.

(ii) Candidates generally found this to be a much more straightforward question than the previous one, and many of them were able to use the Stefan–Boltzmann law correctly to determine the correct answer. Partial credit was also common for candidates who substituted all the values correctly into the equation but then made a mistake with the arithmetic.

Question 10

(a) (i) Most candidates correctly identified the charged particle as an electron, although a significant minority of weaker candidates confused the whole process of X-ray production with positron emission tomography, and gave the positron as the answer here.

(ii) The process of X-ray production by electron bombardment of a metal target was generally well known, although many candidates found it difficult to articulate that the energy of the emitted X-ray photons comes from the kinetic energy of the electrons. Many answers were seen to this question in which candidates attempted to answer a different question from the one asked, and offered responses that attempted to replicate previous mark schemes for a question asking why the emitted X-rays have a range of energies. Such responses were irrelevant to the question asked and could not be awarded credit.

(iii) Many of the weaker candidates found it difficult to start with this question because they did not know how to calculate the energy of the electron from the accelerating p.d. The p.d. was often treated as the energy and directly equated to hc/λ, which is wrong physics and could be awarded no credit. Stronger candidates generally used the correct starting equation and were able to calculate an answer, though many did not appreciate that the nature of the data in this question demands a three significant figure answer.

(b) Weaker candidates were often able to obtain partial credit for a correct starting equation, and many went on to calculate the 2.0% value for the percentage transmitted. Stronger candidates were usually able to carry out the final subtraction from 100 to arrive at the correct answer for the percentage absorbed.

PHYSICS

Paper 9702/43
A Level Structured Questions 43

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. Examiners will only consider symbol equations to be part of a definition if the symbols used are identified.

- 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 had insufficient time in which to complete the paper. There were, however, significant numbers of candidates who did not offer a response to one or more questions. If there is no response, it is never possible for credit to be awarded, so candidates should be encouraged to offer a response to every question on the paper. Even if the candidate is not confident about the answer, it is always possible that the Examiner may be able to award partial credit where there is some response.

Comments on specific questions

Question 1

(a) (i) Only a minority of candidates knew the syllabus 'bookwork' that defines gravitational field as force per unit mass. Many candidates did not give the definition of a quantity but instead answered a different question, asking what is meant by the concept of a gravitational field. As this was such a common misunderstanding of the question, the Examiners did award credit on this occasion for responses that answered the latter question. However, teachers should be aware that candidates are expected to know the syllabus definition that gravitational field is a vector quantity, given by the force per unit mass on an object.

(ii) The comments for **(a)(i)** are also relevant here for the definition of electric field. Candidates are expected to know the syllabus definition that electric field is force per unit positive charge.

(iii) There were many correct similarities and differences stated here. Some candidates gave responses that were correct for forces or fields rather than potentials, such as "both are inversely proportional to distance squared" or "one is attractive and the other is repulsive".

(b) (i) This proof proved to be challenging for many candidates. A significant number of candidates started with the definition of electric field strength as F/Q which is correct, but they needed to extend it to the field due to a point charge. Some candidates were attempted to equate the two field strengths, when they have different dimensions so cannot be equated.

(ii) Candidates who did not reach the required expression in **(b)(i)** were unable to show the numerical value for α here. They did not know the combination of constants that was represented by α. It should be noted that full substitution is required in 'show that' calculations, including all constants. Here it was necessary to see the numerical values for ε_0 and G being used to determine the value of α.

(c) (i) Many candidates used the expression stated in **(b)(i)** to calculate the electric field strength at the surface of the Earth. However, some then gave their answer to two significant figures when the data were given to three significant figures. The requirement for a unit also proved challenging to many candidates. Weaker candidates often tried to answer this by starting once again from first principles, only to find that they did not have enough information to do this.

(ii) There were many correct answers here comparing the directions of the two fields. Some candidates did not realise the significance of the information at the start of **(c)** that the charge carried by the Earth is negative. Some gave the general case and said the direction of the electric field could be towards or away from the surface of the Earth. Some candidates said the directions were opposite, presumably assuming that the charge of the Earth was positive.

Question 2

(a) This question proved to be challenging. Many candidates did not refer to the components of the tension as required. Many referred to components of the weight or thought that the centripetal force was a third force acting, rather than the resultant of the tension and weight. A small number of candidates seemed to think the sphere was oscillating from side to side like a pendulum, rather than describing horizontal circles. The failure to realise the components of the tension at this stage often led to incorrect approaches to the numerical questions later on.

(b) (i) Most candidates were able to use basic trigonometry to show the value of the radius of the circle.

(ii) This 'show that' question proved to be challenging as candidates found it difficult to resolve forces correctly here. Some candidates did not show what they were doing clearly enough, with a numerical value for the weight appearing without the evidence that it was from the multiplication of mass $\times$ gravitational field strength.

(iii) Candidates also found this question difficult. Most candidates tried to apply $k = F/e$ but often did so incorrectly. The extra extension (10.8 cm – 8.5 cm) was not always used and the extra force (3.2 N – (0.29 $\times$ 9.81) N) was rarely used.

(c) (i) Many candidates tried to apply the equations of circular motion here. Only the strongest candidates used $F = ma$ and the horizontal component of the tension as F as necessary.

(ii) Candidates were more successful here, with many gaining credit. The use of circular motion equations, which many had unsuccessfully tried in **(c)(i)**, was necessary here.

Question 3

(a) Candidates found it difficult to demonstrate a good understanding of thermal equilibrium. The idea that thermal energy would still transfer between the two objects, but that the resultant or net transfer was zero, was often not known. This was seen through the omission of the word 'net'. In addition, some candidates did not clarify that the relevant energy was thermal energy.

(b) Candidates needed to refer to the information provided in the graphs. It was common for candidates to refer to the linearity of the relationship, or lack of linearity. Some candidates, however, stated that the relationship between density and temperature for mercury was proportional, which is incorrect. A small number of candidates correctly referred to state changes, but the evaporation of water was not appropriate here.

(c) (i) The majority of candidates correctly stated the boiling temperature of the liquid.

(ii) This calculation proved to be challenging. Many candidates ignored the energy required to raise the temperature of the beaker. A large number of candidates who included the beaker began with the incorrect statement that the energy gained by the beaker was equal to the energy gained by the water. Some candidates calculated the change in temperature correctly as 55 °C but then converted this change into kelvin as if it were a Celsius temperature. This is incorrect physics.

(d) The general shape of the line was correct for most candidates here. Some details were often incorrect, including the approximate gradient of the first part of the line and starting the line from the same temperature.

Question 4

(a) The basic assumptions of the kinetic theory of gases are generally well known. Candidates sometimes referred to the volume of the gas rather than the volume of the particles. Others incorrectly referred to the volume of a single particle.

(b) (i) Most candidates started with the correct equation here. Some candidates then did not go on to use the conditions given in the question which included a pressure of $2p$ when the volume was V. Some candidates did not rearrange the starting equation to make T the subject when they had been asked to determine an expression for T.

(ii) There were many correct responses here, although the line drawn to join Z to X was often a straight line rather than a curve. Some candidates drew more than two dots and some did not add the lines. The lines were needed to show the variation of the pressure with the volume as required by the question.

(iii) Only the strongest candidates correctly completed this table in full. Many candidates found it difficult to correctly apply the first law of thermodynamics for the three changes. They often did not know where to begin on the table, which was by filling in the information for changes already given to them. The information for the remaining changes was deduced from these. Finally, some candidates used letters that were not appropriate, for example a Q to denote thermal energy and a single letter p, which was not an energy.

Question 5

(a) (i) The majority of the candidates knew that the component was a diode and correctly drew the symbol. There were a few other components drawn, such as cells. There was some confusion between a NOT gate (which is not a symbol required by the syllabus) and a diode.

(ii) Whilst most candidates knew that the purpose of the capacitor was to smooth the output voltage, some were under the impression that the capacitor would decrease the output voltage. This may have come from thinking about the exponential curve seen for the discharge of a capacitor. In fact the capacitor increases the average V_{OUT}.

(b) (i) Most candidates correctly determined the frequency of the supply.

(ii) Many candidates were able to use the exponential formula to show the value of the time constant. Some used the total time elapsed (0.04 s) rather than the time interval (0.02 s). Some attempted to use $\tau = RC$, but not enough information was known at this stage for this equation to be helpful.

(iii) There were many correct answers for the capacitance.

(c) Many candidates realised that the output voltage would now be constant. Candidates found it more difficult to explain that this was due to the magnitudes of the positive and negative parts of the input voltage being equal.

Question 6

(a) Candidates generally knew what is meant by a magnetic field. The most common mistake was to refer to the force acting on a charged particle, rather than a moving charged particle. When candidates referred to more than one object that the force was exerted upon, they all needed to be correct.

(b) Most candidates gained credit for drawing field lines that were concentric circles. Most candidates also gained credit for the direction of the field lines. However, for some candidates, the separation of the field lines did not convincingly increase with distance from the wire and for some the separation was definitely intended to be constant.

(c) (i) Most candidates correctly calculated the force per unit length.

(ii) Many correct directions were stated here. However, many candidates did not either remember that currents in opposite directions would cause a repelling force or could use Fleming's left-hand rule to deduce this from first principles.

(iii) Many candidates determined the correct magnitude of current in wire P. However, a large number did not explain their reasoning or did not do so fully enough.

Question 7

(a) The definition of de Broglie wavelength is given in the syllabus. Many candidates quoted this correctly but the word 'moving' was frequently missing. Another common mistake was for candidates to state a formula, which is not correct in this instance.

(b) (i) The majority of candidates correctly stated electron diffraction here. Some candidates referred to the photoelectric effect, the production of X-rays or other phenomena showing they were not familiar with the diffraction of electrons.

(ii) The question asked candidates what could be concluded from the pattern in Fig. 7.2. To be awarded full credit, candidates had to explain that the pattern was indicating diffraction and go from there to explaining that therefore the electrons must be behaving as waves. Candidates often were given credit for stating that electrons were behaving as waves but very rarely explained the pattern.

(c) (i) A common mistake here was to forget the central dark circle which will always be there no matter what the speed of the electrons.

(ii) Candidates generally realised that an increase in p.d. would lead to a greater electron momentum and hence a shorter de Broglie wavelength, but they did not always explain why that changed the pattern.

Question 8

(a) (i) Most candidates correctly showed how to reach the required value of the specific acoustic impedance.

(ii) The majority of candidates were able to complete the table, but not all candidates gave values to three significant figures as required by the question.

(b) (i) Most candidates applied the correct equation here and calculated the correct answer. However, there were some issues with rounding and quoting the final answer to the correct number of significant figures.

(ii) The majority of candidates reached the correct value.

(c) Candidates demonstrated good knowledge of the purpose of the gel used in ultrasound scanning. They knew this would increase the transmission, but some candidates were imprecise in their descriptions, stating that 'most' of the ultrasound was transmitted rather than 'almost all' of the ultrasound. 'Most' can be very much less that almost all of it.

Question 9

(a) Many candidates tried to define half-life in terms of the number of nuclei present. The problem with this definition is that, in many cases, the number of nuclei present does not change. If this is the way that candidates wish to define half-life, then they need to use the words 'radioactive' or 'undecayed' when referring to the nuclei so that the nuclei of the decay product are not part of the definition. A much simpler definition is the time taken for the activity of a sample to halve.

(b) There were many correct lines that were accurately drawn here. However, there were also many candidates that drew the decay curve for carbon-11 rather than the growth curve for boron-11.

(c) (i) Very few candidates realised the key point here that the probability of decay of a nucleus per unit time is constant, which is why the decay is random.

(ii) Many candidates did not realise that the measured count rate from a sample is always less that its activity. The reasons given by those candidates who correctly stated the count rate would be less than the activity were not always sufficiently detailed to gain credit.

Question 10

(a) There were many correct responses here. Some candidates mixed up Hubble's law with Wien's displacement law. The idea of velocity being proportional to distance was often known, but many candidates neglected to talk about the velocity being that of an object emitting light (i.e. a galaxy) and that the velocity was recessional. They also sometimes omitted the fact that the distance was from the observer.

(b) Most candidates calculated the correct value for the radiant flux intensity here. Some weaker candidates started from an incorrect formula, and some forgot to square the distance.

(c) (i) Candidates generally realised that the galaxy was moving away from the Earth, but did not always say that the redshift or Doppler effect was causing the increase in the wavelength of the light received on the Earth.

(ii) There were many correct answers to this two-step calculation. However, a large number of candidates used an incorrect wavelength in the denominator of the redshift equation. Some candidates used the value of the speed of light instead of the recessional speed in the Hubble equation.

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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.
- The numerical answers towards the end of **Question 2** require candidates to show all their working and for the values to be correctly evaluated with appropriate units. 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 how they would perform the experiment in the laboratory using the points given on the question paper to aid their answer. Planning a few key points before answering **Question 1** is useful. Most candidates drew a diagram of a workable experiment, but some did not carefully consider the placement of measuring equipment such as drawing a clamped vertical rule in the correct position or a protractor positioned correctly to measure the angle between the bench and the plane. Only the strongest candidates produced a detailed method to accurately measure the time t while keeping d constant; candidates should be encouraged to carefully consider how each variable is measured. Many candidates were more successful in the analysis section with clear identification of how the constants could be determined. Weaker candidates often did not rearrange the proposed relationship into a suitable equation of a straight line ($y = mx + c$). It is essential for candidates to have experienced practical work in preparation for answering this question.

In **Question 2**, candidates should be familiar with completing a results table for quantities and their uncertainties, and with finding the gradient and y-intercept of a graph. For some candidates, credit was not awarded because the plotted points were not balanced about the line of best fit, the worst acceptable line did not pass through the error bars correctly or coordinates were wrongly read off.

In question parts requiring mathematical manipulation, stronger candidates clearly stated the equation used with correct substitution of numbers, and then calculated the answer and unit. Candidates should be encouraged to set out their working logically so that it can be understood.

Comments on specific questions

Question 1

Most candidates correctly identified the independent and dependent variables. Candidates should then 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 it was expected that candidates would state that d would be kept constant. Credit is not given for simply stating 'control' d since this is just repeating the stem of the question and does not indicate what is meant by 'control'. There was credit for the additional detail of also stating that A and B would be kept constant, but credit was not awarded for stating that the mass should be kept constant as this was too vague. Candidates should be encouraged to use the names of the quantities given in the question paper.

Candidates were awarded credit for a clearly labelled diagram. Diagrams should be drawn of the workable experiment. In this experiment, most candidates drew a diagram of a workable experiment. Some candidates did not include correctly positioned measuring equipment in the diagram. It was important to include a rule in the diagram, positioned correctly to measure the distance *d*. If the rule was positioned vertically it needed to be clamped. A correctly positioned protractor to measure the angle θ was also given credit. Very few candidates included a release mechanism for the cube or cylinder.

Most candidates described the use of a stop-watch to measure the time *t*. Stronger candidates considered how *t* could be measured accurately using light gates connected to a data logger or using a video camera with slow motion playback. The description needed to be clear. Stronger candidates included appropriate additions to their diagram.

When describing the method, candidates should consider how the experiment should be conducted to obtain all the necessary measurements while keeping variables constant. Very few candidates described a suitable method to change angle θ while also keeping distance *d* constant.

Many candidates suggested correct axes for a graph. A significant number of candidates incorrectly suggested plotting t^2 against $1/\sin\theta$. Candidates must explicitly state the quantities to be plotted on each axis either in the text or on drawn axes – credit is not given for just writing $y = mx + c$ under an expression.

Candidates also needed to explain how the graph would confirm the suggested relationship. Candidates need to use the words 'relationship is valid if' and the word 'straight' to describe the line. Some candidates did not gain credit because they incorrectly stated that the line would pass through the origin.

Candidates needed to explain how they would determine values for the constants *H* and *K* from the experimental results using the gradient and *y*-intercept. Candidates needed *H* and *K* to be the subjects of the relevant equations. Credit was not awarded to candidates who did not correctly identify appropriate axes for a graph to plot. Some candidate appeared to not understand that a graph of $1/t^2$ against $\sin\theta$ means that $1/t^2$ is plotted on the *y*-axis and $\sin\theta$ is plotted on the *x*-axis. Some candidates appeared to correctly rearrange the equation for *H* and *K* but omitted the negative sign.

The additional detail section had a maximum of six marks that could be awarded. Candidates should be encouraged to write their plans including appropriate detail; some candidates' answers suggested that they did not have sufficient practical experience. Vague responses were not credited. It is essential that candidates' answers are relevant to the planned experiment rather than general 'textbook' rules for working in the laboratory.

When describing safety precautions, candidates should be encouraged to explain how the precaution proposed is relevant to the experiment. In this experiment, credit was given for a precaution related to the falling cylinder.

Other additional detail that gained credit included a method to increase the value of *t*, e.g. using a large value of *d*. A statement such as 'to reduce the (percentage) uncertainty' on its own did not gain credit – candidates needed to give the method that they will use to reduce the (percentage) uncertainty.

Question 2

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

(b) Many candidates correctly calculated *C* and *T* with an appropriate absolute uncertainty. The most common error was to give *C* as 0.9 (one significant figure) in row 1 instead of 0.89 (two significant figures). All values of *C* here must be given to two (or three) significant figures since the data used to calculate *C* was given to two significant figures.

(c) (i) The points and error bars were straightforward to plot. When plotting points, the diameter of each point should be less than half a small square. Candidates need to take greater care over the accuracy of the error bars and ensure that the error bars are symmetrical.

(ii) Most candidates appear to be using a sharp pencil and a transparent 30 cm ruler. For correctly plotted data, the line of best fit did not pass through both the highest and lowest points. The worst acceptable line was drawn well in general, and many stronger candidates drew a line that passed through all the error bars. Candidates should clearly label the lines drawn. Where a dashed line represents 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 on the line of best fit which are easy to read, i.e. points that are on grid lines. Stronger candidates often included the 10^{-4} power in their calculations which assisted in the interpretation of the gradient in **(e)(i)**. A significant minority of candidates incorrectly calculated the gradient as $\Delta x / \Delta y$.

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 and how the uncertainty is determined from the gradients of the line of best fit and the worst acceptable line.

(d) Most candidates correctly calculated the value of $\ln(V/V_0)$ but incorrectly calculated the absolute uncertainty. The most common incorrect answer was ± 0.04, which came from the incorrect assumption that the percentage uncertainty in $\ln(V/V_0)$ is equal to the percentage uncertainty in (V/V_0) calculated from the percentage uncertainty in V plus the percentage uncertainty in V_0. The correct method here is to calculate either the maximum or minimum $\ln(V/V_0)$ value and determine the absolute uncertainty from the difference. For example, the maximum value would be $\ln(\max V / \min V_0)$.

(e) (i) Candidates should show the substitution of the gradient to determine the value of R. Credit was not given for substituting data values from the table. Candidates are also expected to give the final values of R to an appropriate number of significant figures and a unit which should have the correct power of ten. Since C, V and V_0 were given to two significant figures and t was given to three significant figures, it was expected that R would be given to two (or three) significant figures. Many candidates omitted to allow for the 10^{-4} from the x-axis of the graph.

(ii) Most candidates added the percentage uncertainty in $\ln(V/V_0)$ to the percentage uncertainty in the gradient, clearly showing the numbers that are substituted into the equations. Some candidates determined the percentage uncertainty by maximum and minimum methods. It was essential that the maximum gradient and minimum $\ln(V/V_0)$ were shown to be used to determine the maximum value of R (or vice versa for the minimum value) followed by further working to calculate the percentage uncertainty in R.

(f) There were two likely ways that candidates could determine C. The stronger candidates often recognised that they could divide T by their gradient value, while others substituted values for R and $\ln(V/V_0)$ into the given equation. Candidates needed to show clear and logical working for this question including full substitution of numbers. It was expected that the final answer would be given to at least two significant figures.

The method to calculate the absolute uncertainty in C depends on the method used to calculate C. If the gradient was used, then the candidate should use the percentage uncertainty in the gradient to calculate the absolute uncertainty in C. If the substitution method was used, then the candidate should have added the percentage uncertainties of both $\ln(V/V_0)$ and R and use that value to calculate the absolute uncertainty in C. Candidates should assume that values given in the question paper without an attached uncertainty have a negligible uncertainty which can be ignored.

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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.
- The numerical answers towards the end of **Question 2** require candidates to show all their working and for the values to be correctly evaluated with appropriate units. 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 how they would perform the experiment in the laboratory using the points given on the question paper to aid their answer. Planning a few key points before answering **Question 1** is useful. Drawing circuit diagrams proved to be challenging for many candidates. Some candidates drew circuit diagrams that did not show a workable experiment because components such as voltmeters, oscilloscopes and ohmmeters were inappropriately placed. Many candidates were more successful in the analysis section with clear identification of how the constants could be determined. Weaker candidates often did not rearrange the proposed relationship into a suitable equation of a straight line ($y = mx + c$). It is essential for candidates to have experienced practical work in preparation for answering this question.

In **Question 2**, candidates should be familiar with completing a results table for quantities and their uncertainties, and with finding the gradient and *y*-intercept of a graph. For some candidates, credit was not awarded because the plotted points were not balanced about the line of best fit, the worst acceptable line did not pass through the error bars correctly or coordinates were wrongly read off.

In question parts requiring mathematical manipulation, stronger candidates clearly stated the equation used with correct substitution of numbers, and then calculated the answer and unit. Candidates should be encouraged to set out their working logically so that it can be understood.

Comments on specific questions

Question 1

Most candidates correctly identified the independent and dependent variables. Candidates should then 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 it was expected that candidates would state that *V* would be kept constant. Many candidates appeared to be confused regarding the meaning of *V*. Some candidates incorrectly stated that the potential difference across *R* should be kept constant. There was also credit for the additional detail that *f* would be kept constant. Candidates should be aware that credit is not given for simply stating 'control' *f* since this is just repeating the stem of the question and does not indicate what is meant by 'control'.

Candidates were awarded credit for a clearly labelled diagram. Diagrams should be drawn of the workable experiment. In this experiment, most candidates drew two separate circuits. A circuit was needed to measure *E*; most candidates drew a voltmeter in parallel with coil Q with only a small number of candidates choosing to use an oscilloscope. A common error was to place the voltmeter and a connecting lead such that they were both in parallel with coil Q. There was also credit for the drawing of the circuit diagram for coil P. Many candidates drew a d.c. battery symbol rather than using an a.c. power supply. Some candidates did not place a voltmeter or oscilloscope to measure the potential difference across the resistor and coil P. Other errors in drawing circuit diagrams included adding in an ohmmeter, placing the oscilloscope in series or placing a signal generator in series with a d.c. power supply. Stronger candidates often correctly drew a signal generator or a.c. power supply with an oscilloscope connected in parallel. For candidates who used an oscilloscope there was also credit for describing how the value of V was determined from the oscilloscope using the y-gain and the height of the trace.

Many candidates did not explain clearly how R was determined. Just quoting $R = V / I$ was not sufficient; an explanation was needed as to how the V and I were determined. Stronger candidates usually drew a separate circuit with an ammeter and voltmeter with an explanation of how R was determined either using the equation or graphically. Other strong candidates drew a separate circuit with an ohmmeter.

To analyse the data, candidates needed to determine the frequency of the changing magnetic flux. Stronger candidates described the use of the oscilloscope including how the period T would be determined using the distance across one wave and time-base and stating that $f = 1 / T$. Some weaker candidates misunderstood the term ‘changing magnetic flux’ and suggested the use of a Hall probe and a stop-watch.

Many candidates suggested correct axes for a graph. A significant number of candidates incorrectly suggested plotting E against $1 / R$. Some candidates suggested plotting $(R + k)$ on one of the axes which is not possible because k is unknown. 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.

Candidates also needed to explain how the graph would confirm the suggested relationship. Candidates need to use the words ‘relationship is valid if’ and the word ‘straight’ to describe the line. Some candidates did not gain credit because they incorrectly stated that the line would pass through the origin.

Candidates needed to explain how they would determine values for the constants M and k from the experimental results using the gradient and y-intercept. Candidates needed M and k to be the subjects of the relevant equations. Credit was not awarded to candidates who did not correctly identify appropriate axes for a graph to plot. Some weaker candidates appeared to not understand that a graph of $1 / E$ against R means that $1 / E$ is plotted on the y-axis and R is plotted on the x-axis. Some candidates confused the constant M with the gradient m or omitted V from their equation for M.

The additional detail section had a maximum of six marks that could be awarded. Candidates should be encouraged to write their plans including appropriate detail; some candidates’ answers suggested that they did not have sufficient practical experience. Vague responses were not credited. It is essential that candidates’ answers are relevant to the planned experiment rather than general ‘textbook’ rules for working in the laboratory.

When describing safety precautions, candidates should be encouraged to explain how the precaution proposed is relevant to the experiment. In this experiment, credit was given for precautions relevant to hot coils or resistors. Another safety precaution was to switch off the circuit to avoid a shock from a <u>high</u> voltage.

Other additional detail that gained credit included a method for keeping the coils fixed in position (not just measuring the distance between the coils) and a method to increase the value of E; the use of an iron core or increasing f were two common statements. A statement such as ‘to reduce the (percentage) uncertainty’ on its own did not gain credit – candidates need to state the method that they will use to reduce the (percentage) uncertainty.

Question 2

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

(b) Many candidates correctly calculated V with an appropriate absolute uncertainty. There were some errors due to incorrect rounding (often 3.98 instead of 3.99 in row 2) and some due to incorrect numbers of significant figures. Since d and h were recorded to three significant figures, values of V should have been recorded to three (or four) significant figures.

(c) (i) The points and error bars were straightforward to plot. When plotting points, the diameter of each point should be less than half a small square. Candidates need to take greater care over the accuracy of the error bars and ensure that the error bars are symmetrical.

(ii) Most candidates appear to be using a sharp pencil and a transparent 30 cm ruler. For correctly plotted data, the line of best fit did not pass through both the highest and lowest point. The worst acceptable line was drawn well in general, and many stronger candidates drew a line that passed through all the error bars. Candidates should clearly label the lines drawn. Where a dashed line represents 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 on the line of best fit which are easy to read, i.e. points that are on grid lines. Stronger candidates often included the 10^{-5} power in their calculations which assisted in the interpretation of the gradient and *y*-intercept in **(d)**. A significant minority of candidates incorrectly calculated the gradient as $\Delta x / \Delta y$.

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 and how the uncertainty is determined from the gradients of the line of best fit and the worst acceptable line.

(iv) The majority of the candidates who were awarded full credit set out their working clearly. Stronger candidates often substituted data from the gradient calculation **(c)(iii)** into $y = mx + c$. Some weaker candidates incorrectly read-off the *y*-intercept when $\theta = 20\,°\text{C}$. Other errors seen included candidates incorrectly dividing the *y* value by *mx* or inconsistent use of powers of ten between the gradient and the *y*-axis value used.

When determining the uncertainty in the *y*-intercept, candidates need to show their working including both the gradient and a data point from the worst acceptable line. In calculating the absolute uncertainty, there must be evidence of subtraction between the *y*-intercept of the line of best fit and the *y*-intercept of the worst acceptable line. Some candidates incorrectly attempted to determine the uncertainty in the *y*-intercept by either assuming that the fractional uncertainty in the gradient was the same as the fractional uncertainty in the *y*-intercept or by adding fractional uncertainties.

(d) (i) Candidates should show the substitution of the gradient to determine the value of *Y* and the substitution of the *y*-intercept to determine the value of *Z*. Credit was not given for substituting data values from the table. Candidates are also expected to give the final values of *Y* and *Z* to an appropriate number of significant figures and a unit which should have the correct power of ten. Since θ was given to two significant figures and *d* and *h* were given to three significant figures, it was expected here that both *Y* and *Z* would be given to two (or three) significant figures. Many candidates omitted to allow for the 10^{-5} from the *y*-axis of the graph.

(ii) Most candidates added the percentage uncertainty in the pressure to the percentage uncertainty in the gradient, clearly showing the numbers that are substituted into the equations. Some candidates determined the percentage uncertainty by maximum and minimum methods. It was essential that either the maximum pressure and maximum gradient (or the minimum pressure and minimum gradient) were shown to be used to determine the maximum (or minimum) value of *Y*.

(e) There were many ways that candidates could determine θ. Some candidates used the gradient and *y*-intercept, while others substituted values for *Y* and *Z* from **(d)(i)**. Candidates needed to show clear and logical working for this question as well as considering the powers of ten. It was expected that the final answer would be given to at least two significant figures.

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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.

- The numerical answers towards the end of **Question 2** require candidates to show all their working and for the values to be correctly evaluated with appropriate units. 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 how they would perform the experiment in the laboratory using the points given on the question paper to aid their answer. Planning a few key points before answering **Question 1** is useful. Most candidates drew a diagram of a workable experiment, but some did not carefully consider the placement of measuring equipment such as drawing a clamped vertical rule in the correct position or a protractor positioned correctly to measure the angle between the bench and the plane. Only the strongest candidates produced a detailed method to accurately measure the time t while keeping d constant; candidates should be encouraged to carefully consider how each variable is measured. Many candidates were more successful in the analysis section with clear identification of how the constants could be determined. Weaker candidates often did not rearrange the proposed relationship into a suitable equation of a straight line ($y = mx + c$). It is essential for candidates to have experienced practical work in preparation for answering this question.

In **Question 2**, candidates should be familiar with completing a results table for quantities and their uncertainties, and with finding the gradient and y-intercept of a graph. For some candidates, credit was not awarded because the plotted points were not balanced about the line of best fit, the worst acceptable line did not pass through the error bars correctly or coordinates were wrongly read off.

In question parts requiring mathematical manipulation, stronger candidates clearly stated the equation used with correct substitution of numbers, and then calculated the answer and unit. Candidates should be encouraged to set out their working logically so that it can be understood.

Comments on specific questions

Question 1

Most candidates correctly identified the independent and dependent variables. Candidates should then 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 it was expected that candidates would state that d would be kept constant. Credit is not given for simply stating 'control' d since this is just repeating the stem of the question and does not indicate what is meant by 'control'. There was credit for the additional detail of also stating that A and B would be kept constant, but credit was not awarded for stating that the mass should be kept constant as this was too vague. Candidates should be encouraged to use the names of the quantities given in the question paper.

Candidates were awarded credit for a clearly labelled diagram. Diagrams should be drawn of the workable experiment. In this experiment, most candidates drew a diagram of a workable experiment. Some candidates did not include correctly positioned measuring equipment in the diagram. It was important to include a rule in the diagram, positioned correctly to measure the distance *d*. If the rule was positioned vertically it needed to be clamped. A correctly positioned protractor to measure the angle θ was also given credit. Very few candidates included a release mechanism for the cube or cylinder.

Most candidates described the use of a stop-watch to measure the time *t*. Stronger candidates considered how *t* could be measured accurately using light gates connected to a data logger or using a video camera with slow motion playback. The description needed to be clear. Stronger candidates included appropriate additions to their diagram.

When describing the method, candidates should consider how the experiment should be conducted to obtain all the necessary measurements while keeping variables constant. Very few candidates described a suitable method to change angle θ while also keeping distance *d* constant.

Many candidates suggested correct axes for a graph. A significant number of candidates incorrectly suggested plotting t^2 against $1/\sin\theta$. Candidates must explicitly state the quantities to be plotted on each axis either in the text or on drawn axes – credit is not given for just writing $y = mx + c$ under an expression.

Candidates also needed to explain how the graph would confirm the suggested relationship. Candidates need to use the words ‘relationship is valid if’ and the word ‘straight’ to describe the line. Some candidates did not gain credit because they incorrectly stated that the line would pass through the origin.

Candidates needed to explain how they would determine values for the constants *H* and *K* from the experimental results using the gradient and *y*-intercept. Candidates needed *H* and *K* to be the subjects of the relevant equations. Credit was not awarded to candidates who did not correctly identify appropriate axes for a graph to plot. Some candidate appeared to not understand that a graph of $1/t^2$ against $\sin\theta$ means that $1/t^2$ is plotted on the *y*-axis and $\sin\theta$ is plotted on the *x*-axis. Some candidates appeared to correctly rearrange the equation for *H* and *K* but omitted the negative sign.

The additional detail section had a maximum of six marks that could be awarded. Candidates should be encouraged to write their plans including appropriate detail; some candidates’ answers suggested that they did not have sufficient practical experience. Vague responses were not credited. It is essential that candidates’ answers are relevant to the planned experiment rather than general ‘textbook’ rules for working in the laboratory.

When describing safety precautions, candidates should be encouraged to explain how the precaution proposed is relevant to the experiment. In this experiment, credit was given for a precaution related to the falling cylinder.

Other additional detail that gained credit included a method to increase the value of *t*, e.g. using a large value of *d*. A statement such as ‘to reduce the (percentage) uncertainty’ on its own did not gain credit – candidates needed to give the method that they will use to reduce the (percentage) uncertainty.

Question 2

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

(b) Many candidates correctly calculated *C* and *T* with an appropriate absolute uncertainty. The most common error was to give *C* as 0.9 (one significant figure) in row 1 instead of 0.89 (two significant figures). All values of *C* here must be given to two (or three) significant figures since the data used to calculate *C* was given to two significant figures.

(c) (i) The points and error bars were straightforward to plot. When plotting points, the diameter of each point should be less than half a small square. Candidates need to take greater care over the accuracy of the error bars and ensure that the error bars are symmetrical.

(ii) Most candidates appear to be using a sharp pencil and a transparent 30 cm ruler. For correctly plotted data, the line of best fit did not pass through both the highest and lowest points. The worst acceptable line was drawn well in general, and many stronger candidates drew a line that passed through all the error bars. Candidates should clearly label the lines drawn. Where a dashed line represents 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 on the line of best fit which are easy to read, i.e. points that are on grid lines. Stronger candidates often included the 10^{-4} power in their calculations which assisted in the interpretation of the gradient in **(e)(i)**. A significant minority of candidates incorrectly calculated the gradient as $\Delta x / \Delta y$.

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 and how the uncertainty is determined from the gradients of the line of best fit and the worst acceptable line.

(d) Most candidates correctly calculated the value of ln (V/V_0) but incorrectly calculated the absolute uncertainty. The most common incorrect answer was ±0.04, which came from the incorrect assumption that the percentage uncertainty in ln (V/V_0) is equal to the percentage uncertainty in (V/V_0) calculated from the percentage uncertainty in V plus the percentage uncertainty in V_0. The correct method here is to calculate either the maximum or minimum ln (V/V_0) value and determine the absolute uncertainty from the difference. For example, the maximum value would be ln (max V / min V_0).

(e) (i) Candidates should show the substitution of the gradient to determine the value of R. Credit was not given for substituting data values from the table. Candidates are also expected to give the final values of R to an appropriate number of significant figures and a unit which should have the correct power of ten. Since C, V and V_0 were given to two significant figures and t was given to three significant figures, it was expected that R would be given to two (or three) significant figures. Many candidates omitted to allow for the 10^{-4} from the x-axis of the graph.

(ii) Most candidates added the percentage uncertainty in ln (V/V_0) to the percentage uncertainty in the gradient, clearly showing the numbers that are substituted into the equations. Some candidates determined the percentage uncertainty by maximum and minimum methods. It was essential that the maximum gradient and minimum ln (V/V_0) were shown to be used to determine the maximum value of R (or vice versa for the minimum value) followed by further working to calculate the percentage uncertainty in R.

(f) There were two likely ways that candidates could determine C. The stronger candidates often recognised that they could divide T by their gradient value, while others substituted values for R and ln (V/V_0) into the given equation. Candidates needed to show clear and logical working for this question including full substitution of numbers. It was expected that the final answer would be given to at least two significant figures.

The method to calculate the absolute uncertainty in C depends on the method used to calculate C. If the gradient was used, then the candidate should use the percentage uncertainty in the gradient to calculate the absolute uncertainty in C. If the substitution method was used, then the candidate should have added the percentage uncertainties of both ln (V/V_0) and R and use that value to calculate the absolute uncertainty in C. Candidates should assume that values given in the question paper without an attached uncertainty have a negligible uncertainty which can be ignored.