Principal examiner reports for teachers

Principal examiner reports for teachers summarise what candidates did well and what candidates needed to improve for this examination series only.

This report is to be used in conjunction with the question paper and mark scheme.

For guidance on teaching and learning we provide resources for many of our syllabuses.

Resource	**Where to find it**
Grade descriptions – Grade descriptions describe the level of performance typically demonstrated by candidates achieving the different grades awarded for a qualification.	School support hub Select: Subject > Resource finder > Syllabus and specimen materials
Schemes of work – Schemes of work are designed to support you in your teaching and lesson planning.	School support hub Select: Subject > Resource finder > Teaching and learning
Lesson planning – Guidance on how to plan a lesson.	Lesson planning
Resource plus – There may be additional resources such as teaching packs containing lesson plans, resources and worksheets and videos for aspects of your syllabus.	School support hub Select: Subject > Resource finder > Teaching and learning
Teaching tools	Teaching Tools
Exemplar candidate responses	School support hub Select: Subject > Resource finder > Teaching and learning
Learner guide – A guide for students to help them understand what the course involves.	School support hub Select: Subject > Resource finder > Teaching and learning
Community forums – Do you have a question or something to share? Our online forums are great way to keep up to date with your subject and the global Cambridge community.	Community forum on the school support hub
Access to scripts for this series.	Access to scripts service
Results analysis is available for some syllabuses.	Results analysis
Test maker is available for some subjects.	Test maker

Other services from Cambridge International Education

- **Digital mocks service**
- **Insight assessments**
- **Professional development**
  - Focus on assessment
  - Online marking workshops

PHYSICS

Paper 9702/12
Multiple Choice

Key messages

Candidates performed well on **Questions 1**, **2**, **3**, **4**, **5**, **9**, **12**, **13**, **14**, **16**, **17**, **18**, **19**, **20**, **21**, **22**, **23**, **26**, **29**, **30**, **33**, **35**, **37**, **38**, **39** and **40**.

Candidates performed less well on **Questions 6**, **7**, **8**, **10**, **11**, **15**, **24**, **25**, **27**, **28**, **31**, **32**, **34** and **36**.

Candidates should take care to read the question and all options fully. Options will often include partially correct answers or common misconceptions. Numerical questions will sometimes include common arithmetic errors in applying a correct formula.

Comments on specific questions

Question 6

- Option **B** was a common incorrect answer.
- Candidates selecting **B** confused constant velocity of the toy car at t_2 and t_4 with constant (non-zero) acceleration.
- Candidates need to be familiar with the features of displacement-time graphs and velocity-time graphs.
- Candidates need to be able to distinguish between displacement-time graphs and velocity-time graphs.

Question 7

- All options were popular.
- The most common error was for candidates to calculate the average speed of the car moving along the road from P to Q leading to option **D**.
- Candidates need to understand the difference between average speed and average velocity.
- Some candidates found the correct displacement from P to Q then incorrectly divided this by 3.0 s rather than 4.0 s.

Question 8

- Few candidates selected the correct option **C**.
- Option **A** was a common incorrect answer.
- Many candidates recognised that the person was in equilibrium, and so must experience 0 net force. They assumed that the tension in the rope must equal the weight of the person without considering upthrust.
- Candidates choosing **A** confused the fact that the weight is opposite to and (almost) equal to the tension with the fact that the two forces form a third law pair.
- Candidates need to understand the difference between forces that form Newton's third law pairs, and forces that are equal and opposite and act on the same body.

Question 10

- Options **B** and **D** were common incorrect answers.
- Few candidates were able to determine the tension in the rope by considering the forces acting on the two blocks.
- Candidates needed to form equations for the resultant force acting on each block and use the fact that both blocks would have the same acceleration in order to determine the unknown tension.

- Many candidates chose option **D**, perhaps assuming that block 2 was in equilibrium, without considering the statement that the blocks accelerate.

Question 11

- Option **A** was a common incorrect answer.
- Most candidates recognised that statements 1 and 2 were always equal to the mass of the object.
- Some candidates confused the acceleration of the object with the acceleration of free fall, and so also thought statement 3 was correct.
- Candidates should carefully read the question and check whether the options are always true or only sometimes true.

Question 15

- Option **D** was a common incorrect answer.
- Most candidates recognised that pressure increased with depth and selected options **C** or **D**.
- Some candidates may have confused the relationship between force, pressure and area and how these vary with depth.

Question 24

- All options were popular.
- Candidates need to be able to determine the wavelength for an electromagnetic wave given a frequency.
- Candidates need to be able to recall the approximate wavelengths in free space of the principal regions of the electromagnetic spectrum.

Question 25

- Option **C** was a common incorrect answer.
- Many candidates confused the phase difference of points on a wave for progressive and stationary waves.
- Some candidates did not understand graphical representations of phase difference and so selected options **A** or **B**.

Question 27

- Option **A** was a common incorrect answer.
- Many candidates thought that as the transmission axis of the second filter was horizontal, then no light would pass through the second filter.
- Candidates need to understand that on passing through a polarising filter, light has no ‘memory’ of its previous plane of polarisation. The light incident on the second filter is at an angle of 30° to the transmission axis of the second filter.
- Option **C** was selected by some candidates, who correctly applied Malus’ law to the first filter only.

Question 28

- Options **B** and **C** were common incorrect answers.
- Candidates need to understand that the highest frequency observed by a stationary observer will occur when the source of sound is moving towards the observer with the highest velocity.
- Candidates selecting **B** correctly identified that the car was moving towards the observer without recognising it would not have achieved the highest velocity.
- Candidates selecting **C** correctly identified that the car would have the highest velocity without recognising that the car will be moving away from the observer.

Question 31

- All options were popular.
- Many candidates incorrectly used the formula for a double-slit, rather than the formula for a diffraction grating, leading to option **B**.
- Candidates should recognise that angle of diffraction can be calculated from a measured grating to screen distance and the separation of intensity maxima using trigonometric functions. Angle of diffraction = $\tan^{-1}(7.5/33.5) = 12.62°$.
- Some candidates used the correct formula without halving the distance between the two first-order maxima, and so used an angle of 24.12°. This led to option **C**.
- A few candidates calculated the angle of diffraction as $\tan^{-1}(33.5/7.5) = 77.38°$ leading to option **D**.

Question 32

- Option **A** was a common incorrect answer.
- Many candidates identified the ‘S’ shape of the *I*–*V* characteristic of a filament lamp without recognising that the axes in the question were reversed. The question showed *V*–*I* characteristics.
- Candidates should carefully check the axes in graphs, rather than relying on pattern recognition.

Question 34

- All options were popular.
- Many candidates were unable to manage the algebra in rearranging an equation for resistivity.
- Candidates should be able to apply the formula $R = \rho L/A$ to objects with square, rectangular and circular cross-sections.

Question 36

- All options were popular.
- Many candidates were not able to analyse the network of resistances in order to find the current.
- Candidates should be able to find parallel and series combinations of resistors, and apply Kirchhoff’s laws to solve circuit problems.

PHYSICS

Paper 9702/22
AS Level Structured Questions

Key messages

What candidates did well

- Most candidates were able to use SI base units to assess the homogeneity of an equation in 1(c).
- Most candidates were able to recall relevant equations for calculation problems. In particular the mechanics calculations for **Questions 2(b)(i)**, **2(b)(ii)**, **3(a)(i)** and **4(b)(i)** were generally done well.
- Most candidates showed clear and logical working for the 'show that' **Questions 2(c)(i)** and **5(b)(ii)**.
- Many candidates gave clear concise definitions for **Questions 1(a)**, **2(a)**, **4(a)(i)**, **5(a)(i)**, **5(a)(ii)** and **6(a)**.
- Most candidates correctly identified the location of an antinode in **Question 5(b)(i)**.
- Most candidates could recall an equation for electrical power in **Question 6(c)(iii)**.
- Most candidates showed sufficient working, even where inaccuracies were present.

What candidates needed to improve

- Many candidates used 'by' and 'into' when discussing products and ratios in **Questions 1(a)**, **4(a)(i)** and **6(a)** for example is 'moment is force into perpendicular distance to the pivot'. These terms do not have a consistent meaning globally. Candidates should instead explicitly refer to a product or ratio for example is 'moment is the product of force and perpendicular distance to the pivot'.
- Some candidates rounded their final answers to too few significant figures.
- Many candidates did not consider all of the energy changes involved in the motion of the carriage in **Question 3(a)(ii)**.
- Many candidates gave incomplete or incorrect explanations in the questions that required them.
- Most candidates understood the collision in **Question 2(b)(iii)** to be elastic and did not justify this sufficiently.
- Most candidates did not consider all of the energy changes involved in the motion of the carriage in **Question 3(b)**.
- Most candidates were unable to explain the formation of stationary waves in **Question 5(b)(iii)**.
- Most candidates were unable to use the charge : mass ratio given in **Question 7(c)** to identify particle X. Many were challenged to understand what to do with the information given.

Comments on specific questions

Question 1

(a) **Comprehensive responses**

- Most candidates gave the syllabus definition of force 'rate of change momentum'.

Limited responses

- Many candidates gave 'mass × acceleration'. This is an important relationship for candidates to know, because it is not the definition of force.

(b) **Comprehensive responses**

- Most candidates, typically those who answered part **(a)** correctly, clearly showed the units of momentum and the units of time, and combined these correctly to show the units of force.

Limited responses

- Many candidates did not use the definition of force, and started instead with the units of mass and the units of acceleration.

(c) **Comprehensive responses**

- Most candidate correctly gave the base units of velocity, mass and area.
- Most candidates were able to simplify the units to show that the base units were not equal on both sides of the equation.
- Most candidates stated that unequal base units meant that the equation was not homogeneous.

Limited responses

- Simplification of units was not always accurate in some responses, for example is $s^{-2} \times s^{-1} = s^{-1}$ and this caused them to wrongly deduce that the equation was homogenous.
- Some candidates correctly simplified the units, showing that they were not equal, and incorrectly concluded that this meant the equation was homogeneous.

Question 2

(a) **Comprehensive responses**

- Most candidates correctly recalled that total momentum before and after a collision is conserved.
- Most candidates recalled the condition for conservation of momentum was an isolated system.

Limited responses

- Some candidates did not specify that the <u>total</u> momentum was conserved.
- A few candidates confused conservation of momentum with the principle of moments.
- A few candidates incorrectly specified that the total momentum of a single object remained conserved during a collision.

(b) (i) **Comprehensive responses**

- Most candidates correctly applied the principle of conservation of momentum to find the speed of the sack.

Limited responses

- Most candidates were able to calculate a single correct momentum either before or after the collision, such as $23 \times 3.4 = 78.2$ kg ms^{-1}.
- Some candidates did not include the mass of the sack in their calculation for the total momentum of the system after the collision and so used 160 v rather than 183 v.

(ii) **Comprehensive responses**

- Most candidates stated the formula for kinetic energy.
- Many candidates correctly found the ratio of the two energies
- Some candidates calculated the inverse ratio E_1 / E_2.

Limited responses

- Most candidates stated the formula for kinetic energy.
- Some candidates incorrectly used the mass of the boat only for determining E_2.
- Some candidates gave their answer as an unreduced fraction, or as a fraction rounded to 2 significant figures, rather than a decimal.

(iii) **Comprehensive responses**

- Very few candidates referred to the <u>total</u> kinetic energy being conserved.
- Some candidates related their answers directly to E_1 and E_2, or to their calculated values of kinetic energy from **Question 1(b)(ii)**.
- A few candidates correctly explained the collision was inelastic by reference to the speeds of approach and separation.

Limited responses

- Many candidates referred to the kinetic energy being conserved without referring to 'total' which was insufficient. Candidates needed to refer to <u>total</u> kinetic energy.
- Some candidates made reference to the sack 'sticking to' or 'not rebounding from' the mast of the boat. Many candidates seem to distinguish between elastic and inelastic collisions on the basis of 'sticking' or 'not sticking'. This is not a sufficient justification.

(c) (i) Comprehensive responses

- Most candidates showed that the upthrust and weight acting on the boat were in equilibrium and gave a clear calculation of the weight of the sack and boat, for example, U = W = 183 × 9.81 = 1800 N.

Limited responses

- Some candidates attempted to use the upthrust formula by working backwards from a density calculated in **Question 1(c)(ii)**.
- Some candidates calculated the weight of the sack and boat, and did not explicitly link this calculation to the upthrust acting on the boat. As this was a 'show that' question this connection needed to be stated explicitly.

(ii) Comprehensive responses

- Most candidates correctly used the upthrust formula to determine the density of the water.
- Some candidates did not convert the volume of water from cm^3 to m^3 correctly, and benefited from inaccuracies carried forward.

Limited responses

- Most candidates correctly used the upthrust formula to determine the density of the water.
- Most candidates did not convert the volume of water from cm^3 to m^3 correctly, and benefited from inaccuracies carried forward.
- Many candidates did not correctly round the final answer to 3 significant figures as required by the question. It was common for candidates to round to 1 significant or 4 significant figures.

Question 3

(a) (i) Comprehensive responses

- Most candidate correctly determined the work done.

Limited responses

- Most candidates correctly determined the work done.
- A few candidates did not convert the work done from kJ to J.

(ii) Comprehensive responses

- Most candidates recalled the formula for gravitational potential energy.
- Most candidates used an energy approach, which was the most efficient solution.
- Some candidates were able to correctly determine the change in energy between X and Y, and subsequently arrive at the correct answer.

Limited responses

- Most candidates recalled the formula for gravitational potential energy.
- Many candidates only considered the change in kinetic energy, using E = 16.1 kJ–1.3 kJ = 14.8 kJ.
- Candidates need to also include the work done against resistive forces when calculating the change in energy.
- Some candidates attempted to use kinetic energy to find the speed of the carriage at X and Y, and then used equations of motion to find the change in height. This method could be used successfully, though additional steps were involved compared with the conservation of energy approach.

(b) Comprehensive responses

- Candidates needed to relate the speed to the kinetic energy, and compare the kinetic energies at points X and Z. Very few candidates did this.

Limited responses

- Most candidates incorrectly stated that the speed would be greater at Z than at X.
- Many candidates confused points X and Y, and discussed the gain in kinetic energy of the carriage as the gravitational potential energy decreased.
- Many candidates attempted to link the speed at Z to the steepness of the slope between Y and Z. They often reasoned that as YZ was steeper than XY, the acceleration along YZ would be greater and thus the speed at Z would be greater.

- Some candidates recognised that the gravitational potential energy was the same at X and Z, and so stated that the kinetic energy would also be the same at X and Z, without considering the work done against resistive forces.

Question 4

(a) (i) Comprehensive responses

- Most candidates correctly gave the definition of moment about a point.

Limited responses

- Some candidates omitted ‘perpendicular’ from their description of the distance.
- Some candidates confused ‘displacement’ instead of ‘distance’.
- Some candidates incorrectly described a ‘parallel distance’ or a ‘distance in the direction of the force.’
- A few candidates gave confused definitions of ‘the perpendicular distance between the force and the *point of application* of the force’, rather than the line of action of the force.
- A few candidates confused the definition of the moment due to a force with the principle of moments.

(ii) Comprehensive responses

- Candidates needed to refer to the line of action of the weight passing through point P or the line of action of the weight having no perpendicular distance to P.
- A very few candidates gave a clear and concise explanation.

Limited responses

- Many candidates referred to ‘the perpendicular distance’ being zero, without making it clear that this meant the perpendicular distance between the line of action of the weight and point P.
- Many candidates described a distance ‘perpendicular to P’. Since P is a point, not a line, there cannot be a distance perpendicular to it.

(iii) Comprehensive responses

- Many candidates correctly used an equation for resultant force in the vertical direction to find the angle θ.

Limited responses

- Some candidates confused sin θ and cos θ.
- Some candidates neglected the factor of 2 in the force due to tension and re-arranged incorrectly, for example is sin θ = 13/19.
- A few candidates assumed the angle would be 45°.

(iv) Comprehensive responses

- Most candidates recalled the formula for Young modulus.
- Most candidates correctly determined the area in m^2 and were able to calculate the correct strain.

Limited responses

- Most candidates correctly recalled the formula for Young modulus.
- Some candidates confused stress and strain.
- Some candidates did not use the tension in the wire of 13 N. Common incorrect forces included the weight of the picture, 19 N and double the tension, 26 N.
- Many candidates used the diameter given as a radius, or incorrectly converted the diameter from mm to m.

(b) (i) Comprehensive responses

- Most candidates made use of $s = \frac{1}{2}at^2$ and showed a concise substitution leading to the correct answer.
- Some candidates first determined the velocity of the picture at the instant it hit the ground and made use of another equation of motion to determine t. This method more commonly led to inaccuracies than the first

Limited responses
- Some candidates attempted to use speed = distance / time, neglecting the fact that the picture was falling freely.
- Some candidates determined the correct time though gave an answer rounded to 1 significant figure.

(ii) Comprehensive responses
- Most candidates gave a curved line from the origin.
- Some candidates showed the line with a decreasing positive gradient, possibly confusing this situation with a terminal velocity graph.

Limited responses
- Many candidates drew a straight line from the origin, perhaps confusing a graph of speed against time with the required graph of speed against distance.

Question 5

(a) (i) Comprehensive responses
- Most candidates gave a concise definition in the form 'time for one oscillation/cycle'.
- A few candidates gave a correct definition in the form 'time between adjacent wavefronts'.

Limited responses
- Many candidates attempted to give the definition of period without sufficient precision, such as 'time for one wave/wavelength'.
- A few candidates gave 'period = 1 / *f*' which is a method to calculate period, rather than a definition.

(ii) Comprehensive responses
- Most candidates gave a correct definition for amplitude.

Limited responses
- Some candidates incorrectly described 'height' of a wave rather than maximum displacement.
- Some candidates confused distance with displacement.
- Some candidates referred to the distance between 'crests' or 'troughs' and the 'mean / equilibrium' position without defining crests and troughs.

(b) (i) Comprehensive responses
- Candidates correctly located an antinode on the diagram.

Limited responses
- Candidates confused the location of nodes and antinodes.

(ii) Comprehensive responses
- Most candidates showed their calculation in two steps. Their first step showed the calculation of the value of the wavelength and their second step showed the calculation of the speed by using their value of wavelength.

Limited responses
- Most candidates correctly stated the wave equation.
- Some candidates did not show the calculation of the wavelength explicitly, jumping straight to 0.64 m.
- Candidates should ensure to show all their working for 'show that' questions.

(iii) Comprehensive responses
- Many candidates correctly determined the new wavelength of the wave as 0.53 m.
- Some candidates related the new wavelength to the length of the string and were able to justify that the new wavelength was not a multiple of $L / 2$.
- Some candidates gave incomplete explanations of why a stationary wave would not form, for example reasoning that the string length was 1.8λ, though not explaining why this meant a stationary would not form.

- A few candidates explained that the next frequency for a stationary wave to form was 33 Hz, and so 30 Hz could not be a stationary wave.

Limited responses
- Few candidates calculated the new wavelength of the string.
- Some candidates incorrectly stated that a node would no longer exist at the end of the string, and so a stationary wave would not form.
- Some candidates stated that as the wave was still reflected a stationary wave would form.
- Some candidates stated that the incident and reflected waves would no longer be 'in phase' and so a stationary wave would not form.
- Many candidates were not aware that a stationary wave only forms for certain wavelengths. Candidates are expected to understand the relationship between the string length and the wavelength of waves that can form a stationary wave.

(c) (i) **Comprehensive responses**
- Many candidates correctly found the line spacing, and then applied the diffraction grating equation to determine the order of bright spot.

Limited responses
- Most candidates recalled the diffraction grating equation.
- Many candidates incorrectly used the number of lines per m as the line spacing. This resulted in an order of 9.0×10^{11}. Candidates should recognise when answers are unfeasible, and use this as an indication to check their work.
- Some candidates calculated an order of 1.996 and then incorrectly rounded this down to 1.

(ii) **Comprehensive responses**
- Candidates correctly stated that the separation would decrease.
- Despite an explanation not being required, many candidates gave good explanations related to the diffraction grating formula.

Limited responses
- Candidates incorrectly stated the separation would increase.

Question 6

(a) **Comprehensive responses**
- Most gave a concise definition of the quantity electric current, for example is 'the rate of flow of charge'.
- A few gave the definition of an electric current as 'a flow of charge carriers'.

Limited responses
- Some candidates gave $I = V/R$ in symbols or words.
- Some candidates gave the definition 'number of charged particles (passing a point) per unit time', confusing the total charge with the number of particles.
- A few candidates gave the rate of flow of charge per unit time, defining an incorrect 'rate of change of a rate of change'.
- Very few candidates confused time with seconds.

(b) **Comprehensive responses**
- Most gave a straight line, drawn with a ruler, passing through the correct points.

Limited responses
- A few candidates drew a straight line with a negative gradient from (0, 1.5), that did not pass through the correct terminal p.d. for a current of 1.6 A.
- Many candidates drew a straight line through the origin with a positive gradient, indicating the effect of internal resistance on terminal potential difference was not understood.
- Some candidates did not use a ruler to draw a straight line.

(c) (i) **Comprehensive responses**
- Most candidates showed a correct symbol formula, and substituted into this formula to achieve the correct answer.

Limited responses
- Many candidates recalled the symbol formula for resistivity.
- Some candidates were challenged to re-arrange the formula correctly.
- Some candidates used non-standard symbols for resistivity such as 'r' which can lead to confusion between resistivity and resistance.

(ii) Comprehensive responses
- Most candidates found the lost volts using the relationship $V = E - Ir$.
- They were then able to use either a current-based approach, or a resistance-based approach to determine the value of R.

Limited responses
- Some candidates were able to determine either the lost volts, or the total external resistance of the circuit.
- Few candidates successfully combined these quantities to determine the value of R.
- Some candidates combined all three resistances as if they were in series.
- Many candidates calculated the parallel combination of R and X as 1/R + 1/X, neglecting to then take the reciprocal of this value.
- Some candidates confused the lost volts with the terminal p.d.
- Some candidates used 'R' to mean a general resistance, and this led to some giving the total external resistance of 0.083Ω as their final answer.
- A few candidates wrote only $V = IR$, or gave their answer as the e.m.f over a single resistance, for example is1.5/0.82 = 1.8Ω.

(iii) Comprehensive responses
- Most candidates correctly determined the power.

Limited responses
- Most candidates recalled a correct power formula.
- Most candidates used an incorrect p.d. or resistance in combination with the correct current, for example is $P = 1.8 \times 1.5 = 2.7$ W.

Question 7

(a) Comprehensive responses
- Most candidates gave a concise description.
- Some candidates included a description of the nucleons' structure which was not required.

Limited responses
- Most candidates could identify that the atom has a nucleus and electrons.
- Most candidates identified a nucleus composed of protons and neutrons.
- Some candidates described the presence of a nucleus without describing its structure.
- Some of the candidates only stated that an atom was composed of neutrons, protons and electrons without describing the structure of the atom.
- Some candidates described protons and neutrons located at the 'centre' of the atom, without naming this the nucleus.
- A few candidates thought that a 'nuclear atom' meant a 'radioactive atom' and so attempted to describe the decay of an atom.
- Many candidates misspelled 'neutron', 'nucleus' and 'nucleon'. Candidates are expected to spell technical terms correctly so they can be distinguished from one another.

(b) (i) Comprehensive responses
- Candidates correctly identified alpha-decay.

Limited responses
- The most common incorrect response was beta-plus decay.

(ii) Comprehensive responses
- Candidates correctly identified beta-minus decay.

Limited responses

- Both beta-plus and just 'beta' were common incorrect answers.
- Candidates who use the symbol β should be careful to make clear whether they are referring to β–plus or β–minus decay.

(c) **Comprehensive responses**

- All of the methods in the mark scheme were seen.
- The most common approach was to determine the mass of particle X either in kg or in terms of μ. Those who did so were usually able to identify X as either an electron or positron.
- A significant number gave a final answer of electron, neglecting the positive charge on particle X.

Limited responses

- Many candidates were unable to use the charge : mass ratio given to identify X.
- Many candidates attempted to manipulate the give ratio using a variety of data from the data page, often without any clear approach.
- Some candidates calculated a value of 1837, without realising that this gives a pure number and did not know how to use this to identify X.
- Some candidates guessed that X was a proton or an alpha particle based on the positive charge.

PHYSICS

Paper 9702/33
Advanced Practical Skills

Key messages

Manipulation, measurement and observation

What candidates did well

- Candidates were able to set up apparatus without help and to obtain a set of measurements.
- Most candidates made accurate measurements with suitable precision.

What candidates needed to improve

- Some candidates need to ensure that a micrometre can be used correctly, with the correct units and precision recorded.
- Candidates should ensure that the full range of the independent variable is used, within the limits of the apparatus and method required.

Recording of data and observations

What candidates did well

- Candidates presented their measured values in a single table, with correct column headings.
- Sensible graph scales were used such that all points could be plotted on the grid.

What candidates needed to improve

- Candidates need to ensure that the resolution of measurements is correctly recorded. For example, all measurements using a metre rule with millimetre divisions must be recorded to the nearest millimetre (22.0 cm rather than 22 cm).
- Candidates need to use the correct number of significant figures for calculated values, rounded appropriately, and not confuse this with the number of decimal places in these values.
- Best-fit lines were drawn through the data points in practice experiments, with graphing facilities in spreadsheets used to check whether the lines required adjustment.

Analysis, conclusions and evaluation

What candidates did well

- Most candidates could determine the gradient and intercept from their graph and use $y = mx + c$ to determine the required values.
- Candidates were able to express an uncertainty as a percentage uncertainty.

What candidates needed to improve

- Candidates should demonstrate an understanding that the absolute uncertainty in a measurement is determined by the resolution of the measuring instrument and a judgement of the conditions of measurement.
- When determining if the results support a relationship candidates should take care to use the correct terminology. They should calculate a *percentage difference* and compare this to a given *percentage uncertainty*, rather than use less specific terms such as *experimental accuracy*.
- Experimental limitations in measurement referred to the quantity being measured and included a suggestion to address the limitation.
- Candidates should ensure that suggestions for improvement apply to the experiment being carried out and not based on the recall of other experimental improvements.

Comments on specific questions

Question 1

(a) Comprehensive responses

- Candidates recorded in-range values for x, with an appropriate unit, and θ given to the nearest degree.

Limited responses

- Units were missing for the values of x.
- Values of θ were given to the nearest 0.1° rather than to the resolution of the protractor.

(b) Comprehensive responses

- Tables had correctly labelled columns, with units shown correctly.
- At least six x-values with a range from less than 30 cm to over 45 cm.

Limited responses

- Candidate x-values had a small range or did not extend above 44 cm.
- Candidates show a column heading as θ°, rather than θ / °, or include the degree unit for the sin(90-θ) column.
- Sin(90-θ) values were shown to 3 decimal places rather than the required 3 significant figures. For example, the value of sin(90-θ) for θ = 85 was given as 0.087 rather than 0.0872.
- Sin(90-θ) values were shown truncated rather than correctly rounded. For example, the value of sin(90-θ) for θ = 74 was given as 0.275 rather than the correct 0.276 (rounded 0.02756).

(c) (i) Comprehensive responses

- Candidates plotted all pairs of values with sensible, correctly labelled, scales so that the points covered a large area.
- Points were plotted accurately, using a sharp pencil.

Limited responses

- Some candidates attempted to maximise the area used for plotting points and, in doing so, used scales with 3 cm increments on the x axis or 0.06 increments on the sin(90-θ) axis.
- Including the origin (0, 0 point) on the graph resulted in the points being plotted in a small area.
- The use of a blunt pencil, over-drawing of the points or using filled circles, resulted in plotted points having a large diameter.

(ii) Comprehensive responses

- The best-fit line was drawn carefully using a 30 cm ruler, with a good balance of points along the full length of the line.

Limited responses

- The best-fit line was drawn in two sections, possibly due to the use of a 15 cm or folding ruler, so that the line showed a clear kink or change in direction.
- The best-fit line was drawn to pass through 2 or more points, commonly the first and last points, with an uneven distribution of the remaining points.
- Some candidates ensured that there were three points above and three points below the line. Points were sometimes unevenly distributed, with points above one half of the line and below the other half, so the line could be adjusted.

(iii) Comprehensive responses

- Read-offs from the best-fit line were well-spaced, clearly labelled and recorded accurately.
- Points chosen were on major gridlines for either x or sin(90-θ), minimising the risk of read-off inaccuracies.
- The read-off values were clearly shown in the calculations of gradient and intercept.

Limited responses

- Table values for points not on the best-fit line were used for the gradient or intercept calculations.
- The read-offs for gradient and intercept calculations were close together.

- Inaccuracies were made reading the scales, particularly when awkward scales with increments of 3 or 6 were used, such that the read-off values were incorrect. Some candidates used 2 points for the gradient and a third, different, point for the intercept calculation introducing a further opportunity for inaccuracies.
- Candidates read off the intercept value from the sin(90-θ) axis when there was a false origin (sin(90-θ) value therefore not corresponding to x = 0).

(d) **Comprehensive responses**

- Gradient and intercept values were transferred as p and q respectively.
- Many candidates used the correct units for their gradient and intercept values from **(c)(iii)** as the units for p and q.
- Other candidates recognised that the units for p an q must be such that px and q must have no units, as sin(90-θ) has no units.

Limited responses

- Some candidates did not use their gradient and intercept values and attempted to substitute table values into the equation in order to calculate values of p and q. Even if done correctly, this typically produces values that do not round to the same values as their gradient and intercept.
- Units were either missing or inconsistent with the equation given. A typical inaccuracy was including degrees for the unit of q.
- Some candidates recorded gradient or intercept values to only 1 significant figure and transferred these value to **(d)** without considering the accuracy of the values such that they should be recorded to 2 or 3 significant figures.

Question 2

(a) (i) **Comprehensive responses**

- The value of L was recorded to 0.1 cm, with unit and in the correct range.

Limited responses

- Some candidates recorded their L value as 4 cm which does not show the resolution of the measuring instrument used (in this case a ruler with a millimetre scale).
- A small number of candidates did not follow the instruction and recorded initial L values significantly greater than 4 cm.
- Some candidates did not notice that there was no unit on the answer line and left their L value without a unit.

(ii) **Comprehensive responses**

- A suitable value, recorded to 0.1 cm was given, with a suitable unit of cm or mm.
- Most candidates recognised that it was sensible to use the same units for L and D.

Limited responses

- Some candidates did not notice that there was no unit on the answer line and left their D value without a unit.
- Candidate D value recorded to nearest cm.

(iii) **Comprehensive responses**

- Candidates considered an uncertainty recognising the challenge or variability of the measurement as well as the resolution of the ruler. This is certainly greater than 0.1 cm (the ruler resolution) and, due to the challenge in adjusting the position of the masses to give maximum amplitude, could be as much as 0.5 cm.
- Some candidates followed good practice and repeated measurements of D for this value of L. These candidates were then able to use ± half the range as their absolute uncertainty.

Limited responses

- Many candidates just used the resolution of the ruler to determine their absolute uncertainty as 0.1 cm or 0.05 cm.
- Some candidates used the range of repeated values rather than half range – in many of these cases this did give an absolute uncertainty within the limits of 0.2 cm to 0.5 cm.
- A few candidates did not multiply by 100 to convert their answer to a percentage.

(b) **Comprehensive responses**

- Candidates recorded suitable values of L and D, with their second value of D greater than the first value.

Limited responses

- A few candidates did not change the length of their pendulum so that their second value of L was the same as the first value.
- Some candidates recorded relatively large values of D in **(a)(ii)**, perhaps because the masses had not been correctly adjusted to give maximum amplitude for the oscillation of the pendulum. These candidates then, typically, recorded a second value of D less that the first value.

(c) (i) **Comprehensive responses**

- The equation was rearranged to give $k = D^3 / L$ and two values of k were calculated and recorded correctly.

Limited responses

- Some candidates rearranged the equation as $k = L / D^3$, giving incorrect values of k.
- A few candidates recorded one or both of their k values to 1 significant figure, despite their L and D values having more significant figures.

(ii) **Comprehensive responses**

- Candidates justified the significant figures used for k as based on the significant figures of L and D. For example, 'Number of SF in k is the least number of SF out of the SF in D and L, or one more'.
- Some candidates used correct numbers of significant figures to justify their response. For example, 'My first value of L has 2 significant figures and my first value of D has 3 significant figures. I should therefore use the least of these (or one more) so, in this case, 2 or 3 significant figures is justified for the first value of k'.

Limited responses

- Many candidates made reference to the significant figures in unspecified 'raw values', 'measured values' or 'raw data'.
- Some candidates referred only to either L or D, instead of both. Even if the one referred to does have the least significant figures, they need to show that both measured quantities have been considered.

(d) **Comprehensive responses**

- Many candidates calculated a percentage difference and determined whether this was less than the given percentage uncertainty of 15 per cent in order to support the relationship.
- Some candidates used the alternative approach of applying the 15 per cent criterion to their k values and showing an overlap of the ranges to support the relationship.

Limited responses

- Candidates made a comparison to a percentage uncertainty other than the given 15 per cent. This could be their value from **(a)(iii)** or some other numerical value.
- Candidates attempted an explanation in terms of unspecified 'experimental accuracy' or other vague term, without reference to the given 15 per cent.
- Some candidates were under the impression that the difference should be 15 per cent in order to support the relationship, with a response such as 'the relationship is not valid since the difference of 12 per cent is not equal to 15 per cent'.
- Some candidates attempted the overlap of ranges method without showing working clearly and without a clear comparison of values.

(e) (i) **Comprehensive responses**

- Many candidates recorded suitable values for w and t, showing correct use of a micrometre for the measurement of t.

Limited responses
- Some candidates did not convert their millimetre values for t into centimetres. A t value of 0.52 mm should be recorded as 0.052 cm, with the units given on the answer line. Candidates should recognise that a recorded value of 0.52 cm could not be correct for the thickness of a hacksaw blade.
- Some candidates recorded low-resolution values of t, typically 0.1 cm, showing that the micrometre had not been used. Some of these candidates made reference to 'use of micrometre' as an improvement in **(f)(ii)**.
- A few candidates recorded values for t showing incorrect use of the micrometre, or confusion between the main scale and the barrel scale.

(ii) Comprehensive responses
- The value of E was calculated correctly with consistent units used for D and L (and hence k), w and t. Answers were recorded correctly in scientific notation and given to 2 or 3 significant figures.

Limited responses
- Some candidates recorded a value of E with an incorrect power of ten, typically by not using centimetres throughout the question. If candidates used metres for their values of L and D it was rare for a correct conversion of k values to be made at this stage.
- A few candidates made an arithmetic inaccuracy in the calculation, typically not cubing their value of t or switching values of t and w.

(f) (i) Comprehensive responses
- Candidate considers each of the measured values in turn, stating the quantity and describing a challenge with that measurement. Each response usually begins, for example, 'It was more complex to measure L accurately because …'.
- A few candidates made correct reference to a judgement needed. For example, 'It was more complex to determine D because it was hard to judge for which position of the masses the amplitude of the pendulum was greatest' or 'There were inaccuracies in the measurement of L as it was more complex to judge the precise position of the centre of mass of the pendulum'.
- Most candidates recognised that two values of L, with corresponding values of D, is insufficient to determine a relationship.

Limited responses
- Responses noted a challenge without stating the quantity being measured. A typical response would be 'There was parallax inaccuracy when using the ruler'.
- Responses noted the quantity without describing the challenge, for example 'It was more complex to measure L'.
- Candidates made reference to measuring the amplitude of oscillation of the pendulum, without recognising that they needed to compare amplitudes for different values of D in order to determine the value of D that give maximum amplitude.
- Candidates noted challenges remembered from other questions involving oscillations such as challenges with timing – a problem that does not apply here.
- Some candidates suggest that wind, or other air movement, will affect the oscillation. This will have a negligible effect on the oscillations of a metal pendulum bob.

(ii) Comprehensive responses
- Candidates consider each of their limitations in turn and suggest improvements in the method, for which they didn't have time, or equipment that was not provided.
- A few candidates recognised that the experiment should be repeated for different values of L in order to give more evidence to support the relationship L and D.

Limited responses
- Many candidates suggested repeating measurements and calculating averages. It is expected that, where possible and relevant, candidates will repeat and average measurements as good practice.
- Many candidates suggested the use of a video camera, sometime with a timer, to record the experiment and to watch frame-by-frame. This would only be appropriate to improve the measurement of the period of the oscillation. The use of video in this case would require a ruler to be in view so that amplitude could be determined.

- Some candidates recognised that measuring the diameter of the pendulum bob (or the masses) would enable radius to be determined. This needs a method of measurement of diameter, other than using the ruler provided, to give a full description of the improvement.
- Some candidates offer vague or irrelevant suggestions for improvement. Examples include, ‘Carry out the experiment in a closed environment to eliminate air movement’, or ‘Check that the bench is steady and the equipment works before starting the experiment’.

PHYSICS

Paper 9702/42
A Level Structured Questions

Key messages

What candidates did well

- Candidates generally provided responses to all question-parts in the paper, with cases where there were question-parts left blank being rare.
- Candidates generally read the questions carefully and attempted to provide answers to the questions asked.
- Candidates generally knew the equations of the syllabus well and were often successful in the calculation questions. Even candidates that did not reach the correct final answers were able to demonstrate knowledge of the correct starting equations, by setting out their working clearly.
- The routine bookwork was generally well-known, with many candidates providing correct answers to the questions asking for definitions of quantities and the meanings of concepts.

What candidates needed to improve

- When deciding how many significant figures to present a numerical answer to, candidates need to consider carefully the precision of the data in the question and take care to avoid presenting a final answer to a precision that is less than that justified by the data.
- When dealing with quantities where the sign is meaningful, candidates need to take more care over the sign that is used. This is particularly important when dealing with energies and energy transfers in questions involving thermodynamics.
- When providing descriptive answers, candidates need to use the technical language of the syllabus accurately and to take care to avoid contradicting themselves.

Comments on specific questions

Question 1

(a) **Comprehensive responses**

- Candidates gave the correct definition of the radian.

Limited responses

- Candidates needed to make clear that the radian is an angle.
- Candidates needed to be clear that the defining condition is that the arc length equals the radius.
- Candidates sometimes confused the definition of the unit ‘radian’ with the definition of the quantity ‘angle in radians’.

(b)(i) **Comprehensive responses**

- Candidates obtained the correct answer.

Limited responses

- Candidates usually contained the correct starting equation.
- Candidates often obtained answers of either 1.6 m or 4.8 m, due to confusion over how the radius of the roundabout relates to the symbol *R* as defined in the question.

(ii) **Comprehensive responses**

- Candidates obtained the correct answer.

Limited responses
- Candidates usually contained the correct starting equation.
- Candidates needed to realise that the angular frequency is equal for every point on the roundabout.

(iii) Comprehensive responses
- Candidates obtained the correct answer.

Limited responses
- Candidates usually contained a correct version of the starting equation.
- Candidates needed to realise that the radius at position Y is two thirds of the radius of the roundabout.

(c) Comprehensive responses
- Candidates placed all three ticks in the correct boxes.

Limited responses
- Candidates placed some of the ticks in the correct boxes.
- Some candidates needed to realise that angular velocity is uniform across the whole roundabout whereas linear speed increases with distance from the centre.

Question 2

(a) Comprehensive responses
- Candidates gave the correct definition of electric field.

Limited responses
- Candidates realised that electric field strength is the force per unit charge.
- Candidates needed to realise that electric field is a vector quantity and that the direction is correctly established by making clear that electric field is force per unit positive charge.

(b) (i) Comprehensive responses
- Candidates gave the correct field line pattern with the field direction correctly indicated.

Limited responses
- Candidates usually indicated the correct field direction.
- Candidates needed to ensure the field lines were straight and perpendicular to the plates.
- Candidates needed to make sure the lines extended all the way from plate to plate.
- Candidates needed to show field lines that were uniformly distributed within the field region.

(ii) Comprehensive responses
- Candidates clearly described the correct directions for the gravitational and electric forces.
- Candidates correctly related the direction of the electric force to the positive sign of the charge.

Limited responses
- Candidates often drew the correct conclusion with some supportive reasoning.
- Candidates needed to be clearer in naming the two relevant forces.

(c) (i) Comprehensive responses
- Candidates obtained the correct expression.

Limited responses
- Candidates often either used different symbols from the ones defined in the question or gave an expression for a different quantity from the one asked for.

(ii) Comprehensive responses
- Candidates obtained the correct expression.

Limited responses
- Candidates often either used different symbols from the ones defined in the question or gave an expression for a different quantity from the one asked for.

(d) Comprehensive responses
- Candidates obtained the correct answer.

Limited responses
- Candidates often made correct use of the equation $W = mg$ and used the correct value for g.
- Candidates needed a correct expression for the wright in part **(c)(ii)** in order to be able to deduce the correct answer.

(e) Comprehensive responses
- Candidates gave a correct statement about the directions of the two forces or the direction of the resultant force on the droplet.
- Candidates correctly described the motion of the droplet as accelerating downwards.

Limited responses
- Candidates often did realise that the motion of the droplet is downwards.
- Candidates needed to me clear that the droplet is accelerating, rather than just moving.
- Candidates needed a clear explanation in terms of the directions of the forces acting.

Question 3

(a) Comprehensive responses
- Candidates gave the correct definition of specific latent heat of fusion.

Limited responses
- Candidates usually realised that specific latent heat relates to a change of state.
- Candidates needed to be clear that the relevant state change is the solid-liquid state change.
- Candidates needed to be clear that this state change happens at constant temperature.
- Candidates needed to be clear that the numerical quantity is a thermal energy per unit mass.

(b) Comprehensive responses
- Candidates correctly compared the change in volume of the substance for the two state changes.
- Candidates clearly related the larger change in volume for vaporisation to greater work being done against the atmosphere and hence greater thermal energy being needed.

Limited responses
- Candidates often discussed molecular separation in the liquid and gaseous states, without addressing the comparison of the changes in separation during fusion and vaporisation.

(c) Comprehensive responses
- Candidates obtained the correct answer.

Limited responses
- Candidates usually knew the relevant starting equation $Q = mc\Delta\theta$.
- Candidates did realise that an application of the principle of conservation of energy was required.
- Candidates often omitted one of the terms in the conservation of energy application, usually forgetting that the ice undergoes two stages of warming (one from –18 °C to 0 °C and the other from 0 °C to the final temperature).
- Many candidates who did have all four terms in the conservation of energy equation used the value of 2.11 kJ kg^{-1} $°C^{-1}$ for the specific heat capacity for both warming stages, forgetting that once the ice has melted the correct value is 4.19 kJ kg^{-1} $°C^{-1}$.

Question 4

(a) **Comprehensive responses**
- Candidates gave the correct meanings for the two symbols.

Limited responses
- Candidates often confused the concepts of internal energy and change in internal energy.
- Candidates needed to realise that in the first law of thermodynamics, the signs of the terms is crucial, and so the direction of energy change or transfer must be clearly stated for both terms.

(b) (i) **Comprehensive responses**
- Candidates showed a full substitution of values from the question into equation $W = p\Delta V$ to clearly show how the required value of W is calculated.

Limited responses
- Candidates usually knew the starting equation $W = p\Delta V$.
- Candidates sometimes used a value for ΔV without showing where it came from using the data in the question.

(ii) **Comprehensive responses**
- Candidates correctly used the decrease in volume to explain the positive sign for W.

Limited responses
- Candidates sometimes stated the sign for W without providing the explanation asked for in the question.

(iii) **Comprehensive responses**
- Candidates explained that, because thermodynamic temperature is proportional to volume and internal energy is proportional to thermodynamic temperature, the internal energy must be proportional to volume.
- Candidates then went on to explain that, because the volume has become a quarter of the initial volume, the internal energy becomes a quarter of the initial internal energy.

Limited responses
- Many candidates attempted a qualitative explanation of why the internal energy decreased, without explaining why the final value is 3.6 kJ.

(c) **Comprehensive responses**
- Candidates obtained the correct answer.

Limited responses
- Candidates often deduced correctly that the magnitude of the change in internal energy is 10.8 kJ.
- Candidates that deduced the correct magnitude of Q needed to realise that the sign of Q must be negative because thermal energy transfer is away from the gas.

Question 5

(a) **Comprehensive responses**
- Candidates gave the correct meaning of the Avogadro constant.

Limited responses
- Candidates needed to be clear that the Avogadro constant is a number of particles.

(b) **Comprehensive responses**
- Candidates made three correct deductions about the gas.

Limited responses
- Many candidates described the graphs without attempting to make deductions from them.
- Candidates sometimes made deductions that were not about the gas (for example, the value of the Boltzmann constant).

- Candidates sometimes deduced a numerical value for a property of the gas, without a correct unit or to insufficient precision.
- With some properties, candidates needed to be clearer in describing what the property was (for example, in calculating a 'mass', they needed to be clear whether the mass calculated was of one molecule or of the whole gas).

(c) (i) **Comprehensive responses**

- Candidates drew the correct conclusion with a correct supporting explanation.

Limited responses

- Candidates sometimes drew the correct conclusion, and then needed to explain the reasoning in terms of the graphs making it clear that the gas is ideal.

(ii) **Comprehensive responses**

- Candidates gave two correct assumptions of the kinetic theory.

Limited responses

- Candidates needed to be clear in their statements that the behaviour described relates to molecules in the gas rather than to the entire gas.

Question 6

(a) **Comprehensive responses**

- Candidates described both of the characteristic properties of simple harmonic motion clearly and correctly.

Limited responses

- Candidates usually knew that, in s.h.m., acceleration is directly proportional to displacement from the equilibrium position.
- Candidates often needed to be clearer that these two quantities always have the opposite direction to each other.

(b) (i) **Comprehensive responses**

- Candidates obtained the correct answer.

Limited responses

- Candidates usually knew the starting equation $\omega = 2\pi / T$.
- Candidates were sometimes unsure that the value of ω is the 6.9 value in the equation given in the question.

(ii) **Comprehensive responses**

- Candidates knew or deduced the equation $v_0 = \omega x_0$ and showed clearly the substitution of the values for ω and x_0 to show how the value of v_0 is calculated.

Limited responses

- Some candidates showed the correct substitution then attempted to carry out some unit conversions, without realising that the value of x_0 in mm directly gives v_0 in mm s –1.
- Some candidates, using the general expression for v from the formula sheet, needed to realise that the value of x for which v has its maximum value is zero.

(c) (i) **Comprehensive responses**

- Candidates obtained the correct answer.

Limited responses

- Candidates usually knew the starting equation $E = \Delta BA / t$.
- Most candidates applied the unit conversion factor to the 6.0 cm value correctly.
- Candidates often incorrectly used the area of the rectangular coil for the value for A.
- Some candidates did almost everything correctly, though needed to realise that there were two sides of the coil cutting flux (and therefore contributing to the induced e.m.f.).

(ii) Comprehensive responses

- Candidates showed well-drawn sinusoidal curves of the correct period, amplitude and phase.

Limited responses

- Candidates often drew sinusoidal curves of the correct period and frequency.
- Many candidates drew a sine curve rather than a cosine curve without realising that the phase is determined by maximum e.m.f. when the flux is being cut at the greatest rate.
- Some candidates drew saw-tooth or square waves rather than sinusoidal curves.

Question 7

(a) Comprehensive responses

- Candidates correctly described the meaning of r.m.s. current.

Limited responses

- Candidates needed to realise that r.m.s. current is neither the mean current nor the peak current.
- Candidates needed to realise that the √2 relationship between peak and r.m.s. current is not the meaning of r.m.s. current, and only applies to the specific case of a current that varies sinusoidally.
- Some candidates that did know that r.m.s. current is the steady current that produces the same power in a resistor needed to be clear that it is the mean power that is the same.

(b) (i) Comprehensive responses

- Candidates obtained the correct answer.

Limited responses

- Some candidates gave the peak power rather than the mean power.

(ii) Comprehensive responses

- Candidates obtained the correct answer.

Limited responses

- Candidates usually knew the relevant starting equation $P = I^2R$.
- Many candidates needed to realise that use of the mean power in this equation leads directly to the r.m.s. current.

(c) (i) Comprehensive responses

- Candidates identified the correct circuit symbol.

Limited responses

- Some candidates needed to realise that the function of a capacitor in the circuit would be to produce smoothing rather than the original rectification.

(ii) Comprehensive responses

- Candidates showed well-drawn curves of the correct shape, with either the middle half-section or the outer two quarter-sections reduced to zero power.

Limited responses

- Some candidates did know that half of the original power is removed to zero.
- Many candidates drew curves that showed non-zero power throughout.
- Some candidates thought that the peak power was reduced.

(iii) Comprehensive responses

- Candidates obtained the correct answer and reasoned it correctly in terms of the mean power being half of the original mean power.

Limited responses

- Some candidates thought that it was the r.m.s. current, rather than the mean power, which is halved during half-wave rectification.

- Candidates often obtained the correct numerical answer without providing the supporting explanation.

Question 8

(a) **Comprehensive responses**

- Candidates used the photon model to give well-reasoned explanations of how discrete spectral lines provide evidence for discrete energy levels.
- The explanations contained clear links from one concept to another in each step of the reasoning.
- The explanations made correct use of the relevant technical terminology.

Limited responses

- Many candidates did know that a photon is a discrete packet of energy whose energy depends on the wavelength of the electromagnetic radiation.
- References to 'energy' were often vague, and needed to be clearer in which energy was being discussed in any given point (whether photon energy, energy absorbed or emitted by electrons, differences in energy levels or the energy levels themselves).
- Some candidates made no reference to the photon model at all.
- Some candidates gave responses that discussed the photoelectric effect and threshold frequencies, rather than addressing the topic of the question.

(b) (i) **Comprehensive responses**

- Candidates gave clear explanations of the effect of recession of the galaxy on the wavelengths observed.

Limited responses

- Many candidates did realise that the recession of the galaxy leads to redshift.
- Some candidates thought that redshift was due to the distance away of the galaxy rather than its relative motion to the observer.

(ii) **Comprehensive responses**

- Candidates showed observed spectral lines to the right of the original lines, with each line being shifted by approximately the same amount or by slightly increasing amounts with increasing initial wavelength.

Limited responses

- Most candidates showed the lines shifting in the correct direction, realising that observed wavelength is greater than the emitted wavelength.
- Some candidates showed lines in which the extent of the redshift was variable.
- Some candidates attempted to draw in the blank space under the question rather than on Figure 8.1. As a result, the original diagram was not included in their response.

(iii) **Comprehensive responses**

- Candidates obtained the correct answer.

Limited responses

- Many candidates did get as far as use of Hubble's law to determine the speed of recession of the galaxy.
- Candidates often were challenged with the substitution of the correct values into the Doppler equation, with many needing to realise that the lowest frequency line is the one with the greatest wavelength.
- Some candidates correctly calculated $\Delta\lambda$ and then subtracted it from 656 rather than adding it.
- Some candidates needed to realise that the precision to which the final answer can be justified is three significant figures, and that they should therefore give an answer that is correct to the nearest nm.

Question 9

(a) **Comprehensive responses**

- Candidates correctly stated that radioactive decay is the spontaneous emission of ionising radiation from unstable nuclei.

Limited responses

- Many candidates did realise that radioactive decay is something that happens to unstable nuclei.
- Candidates were often unclear about what was being emitted or that the emission is spontaneous.
- Some candidates gave descriptions of nuclear fission.
- Some candidates gave a definition of half-life rather than answering the question asked.

(b) (i) **Comprehensive responses**

- Candidates obtained the correct answer with the correct unit to the expected three significant figure precision.

Limited responses

- Most candidates were able to substitute the half-life into the equation λ = ln2 / half-life.
- Many candidates gave the correct unit for the value of half-life used (whether in min or s).
- Some candidates were unsure what the unit should be.
- Many candidates needed to realise that the three significant figure value for half-life demands a three significant figure value for decay constant.

(ii) **Comprehensive responses**

- Candidates obtained the correct answer to the expected three significant figure precision.

Limited responses

- Some candidates calculated the correct activity and then gave a final answer to insufficient precision.
- Many candidates were challenged to substitute the correct values into the exponential equation.
- Some candidates needed to realise they needed to use the exponential equation.

(iii) **Comprehensive responses**

- Candidates drew a curve with the correct curvature passing within tolerance through the correct key points.

Limited responses

- Candidates usually drew a line that started at the correct activity at time $t = 0$.
- Some candidates drew straight lines or curves that curved the wrong way.
- Many candidates were challenged to draw curves that passed through the correct values for activity at both times $t = 12.0$ min and $t = 20.0$ min.

(c) **Comprehensive responses**

- Candidates clearly understood that activity relates to all the radiation emitted whilst measured count rate relates only to the part of that radiation that is detected (which is only ever a small fraction of what is emitted).
- Candidates gave clear descriptions of some of the reasons for this, expressed making correct use of the relevant technical terminology.

Limited responses

- Many candidates were able to give at least one reason why not all the emitted radiation is detected.
- Candidates were often unclear about what is emitted by the sample, with many thinking that is is either ‘radioactive particles’ or the daughter product that is emitted.
- Some candidates thought that the difference between activity and count rate is that one is theoretical and one is practical. These candidates thought that the random nature of decay was relevant (meaning that what actually happens is not necessarily what was predicted), and

need to realise that that the random variations of decay will affect both activity and measured count rate equally.
- Some candidates thought that detection of background radiation was a relevant factor, without realising that background radiation will result in a higher measured count rate rather than a lower one.

Question 10

(a) (i) Comprehensive responses
- Candidates clearly explained that reflected ultrasound vibrates the crystal in the transducer, causing an induced e.m.f.

Limited responses
- Many candidates did realise that ultrasound causes distortion.
- Candidates needed to be clearer on what the object is that is being distorted, and that those distortions are a vibration or a repeated expansion and contraction.
- Some candidates needed to realise that 'stress' is a term that does not convey distortion (though rather the application of a force), whereas the term they needed to convey distortion was 'strain'.
- Candidates were often vague about how the e.m.f. was being produced, omitting reference to induction or generation.
- Some candidates discussed how the piezoelectric crystal produces ultrasound using an applied p.d., rather than how it detects a received ultrasound pulse.

(ii) Comprehensive responses
- Candidates gave a correct definition of specific acoustic impedance.

Limited responses
- Most candidates knew that specific acoustic impedance is the product of a density and a speed.
- Many candidates needed to be clearer about what is meant by speed and density in this equation.

(b) (i) Comprehensive responses
- Many candidates obtained the correct answer to the expected three significant figure precision.

Limited responses
- Some candidates calculated the correct answer then rounded it to an insufficient precision.
- Some candidates used the speed of sound for air or glass rather than for water.

(ii) Comprehensive responses
- Candidates obtained the correct answer.

Limited responses
- Many candidates carried out the calculation correctly then gave an answer to a different precision than the one asked for in the question.
- Some candidates substituted correctly into the equation, then forgot to square at the end in carrying out the calculation.

(iii) Comprehensive responses
- Candidates articulated clearly, using correct technical terminology, that because the specific acoustic impedances are so different, the intensity reflection coefficient is almost 1, with the result that virtually all of the ultrasound is reflected and none of it is transmitted at the boundary.

Limited responses
- Many candidates did realise the significance of the specific acoustic impedances.
- Some thought that one being larger or smaller than the other was relevant, rather than just the two of them being very different.

- Candidates needed to be less comparative in the tone of their responses, so that (for example) it is not just ‘more’ of the ultrasound that is reflected, though almost all of it.
- Some candidates mis-read the question and thought that it was still asking about the water-glass boundary in part **(b)(ii)**.
- Some candidates discussed the refraction of the ultrasound that passes into the glass, rather than focusing on the implication of the data in Table 10.1, that almost none of it does.

PHYSICS

Paper 9702/52
Planning, Analysis and Evaluation

Key messages

What candidates did well

- In **Question 1**, candidates identified independent, dependent variables and the quantities that needed to be kept constant.
- Candidates were often able to identify an appropriate graph to analyse their measurements.
- In **Question 2**, candidates were able to appropriately work through the algebra to obtain expressions for the gradient and *y*-intercept, complete the table of results and plot the data points on the graph.
- Calculate percentage uncertainty.

What candidates needed to improve

- 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.
- Draw workable circuit diagrams using correct circuit symbols.
- Include detail in how measurements are taken.
- In **Question 2**, draw lines of best-fit with a balance of data points about the line.
- Candidates should show all their working in the numerical answers towards the end of the question.
- Use appropriate units and powers of ten when evaluating quantities.

Comments on specific questions

Question 1

Comprehensive responses

- Most candidates correctly understand that the value of C needed to be varied and e needed to be determined for each value of C.
- Explicitly stated that V and k needed to be kept constant.
- The diagram included the clamping of the block and motor to the bench and also fixing the rule to determine e.
- Correct circuit symbols were used in the circuit diagram.
- A two-way switch or two switches were positioned so that the capacitor could be charged without the motor operating and also for the capacitor to discharge though the motor.
- Explained clearly the method of determining e using a rule in terms of the original length of the spring combination.
- Explained how k was determined by describing an experiment using a mass and wither giving an appropriate equation with k as the subject of describing how k could be determined from a relevant graph.
- Explained how to determine C by describing a timing experiment to discharge a capacitor through a resistor and
- Most candidates explicitly stated plotting a graph with e^2 on the y-axis against C on the *x*-axis. Other graphs included lg e against lg C.
- Many candidates explained how the graph would confirm the suggested relationship correctly by stating that the relationship between $e^2$and C would be valid if a straight line passing through the origin could be drawn. Candidates who stated plotting a graph of lg e against lg C needed to indicate that the relationship between $e^2$and C would be valid if a straight line with a gradient of 0.5 could be drawn.
- Many candidates also identified how β was determined – β needed to be the subject of the equation.
- Described how the hazard of a spring being released at speed could be reduced by using a safety screen around the apparatus to prevent injury to other people.

- Explained how larger measurable values of *e* could be determined by using a larger value of *V* or using springs with a smaller value of *k*.

Limited responses
- Some candidates repeated the stem of the question and used the word 'control'.
- A minority of candidates did not identify that *V* needed to be kept constant. Many of these candidates thought that changing *V* would change the capacitance of the capacitor.
- Included unnecessary equipment in their circuit diagrams.
- Explained the determination of *C* in terms of the current in a charge or discharge circuit being constant.
- Some candidates did not explicitly state the quantities to be plotted on each axis. A few of these candidates $y = mx + c$ below an expression which did not meet the requirements of the question.
- Some candidates suggested an appropriate graph. The method for using the graph to identify whether the given relationship was true was not always clearly explained, with omission of the link that the straight line would pass through the origin. Other candidates did not explain how the constant β was determined.

Question 2

(a) **Comprehensive responses**
- Most candidates transformed the equation into a logarithmic format using the available white space within the question and correctly identified the gradient and *y*-intercept.
- The expression for the *y*-intercept was often given as either $\lg\left(\sqrt{\frac{\gamma R}{M}}\right)$ or $\frac{1}{2}\lg\left(\frac{\gamma R}{M}\right)$.

Limited responses
- A few candidates either used 'ln' instead of 'lg' or omitted 'lg'. A small minority did not include *M* within the square root.

(b) **Comprehensive responses**
- Many candidates understood that *v* was recorded to three significant figures so lg v needed to be recorded to three (or four) decimal places.
- Most candidates correctly determined the absolute uncertainty in lg *v*.

Limited responses
- Some candidates incorrectly rounded values, for example is lg (357) = 2.5526682… was sometimes incorrectly rounded to 2.552 rather than 2.553 or 2.5527.
- Some candidates appeared to have copied the absolute uncertainties in *v* to the absolute uncertainties in lg *v* with some dividing by 1000 to give 0.002 etc.
- A few candidates appeared to have used ±2 rather than ±3 for the last two rows.

(c) (i) **Comprehensive responses**
- Most candidates plotted each data point within half a small square often using a small cross. The diameter of each point was less than half a small square.
- Error bars were accurately drawn with a clear small line at the end of each bar.

Limited responses
- A few candidates did not plot the points to the nearest half a small square.
- Some candidates mis-read the scale on the *y*-axis.
- A common inaccuracy was to plot an error bar half the length it should have been.

(ii) **Comprehensive responses**
- Used a sharp pencil and a transparent 30 cm ruler so that they could draw a line where the data points were balanced about the line.
- Drew either the steepest or shallowest line that passed trough all the data points.

Limited responses
- Some candidates did not draw a straight line with a balance of points, often incorrectly drawing a line from the top plot to the bottom plot.
- Some candidates referred to a limiting line, with identification of this as the steepest or shallowest line passing through all the error bars not always included.

(iii) Comprehensive responses

- Most candidates clearly demonstrated the points that they used to calculate the gradient often selecting two points on the line of best fit which are easy to read, for example is the points are on grid lines.
- Most candidates indicated the coordinates that they had used from the limiting line to determine the gradient of the limiting line and then showed how the absolute uncertainty was determined by finding the difference in gradients of the line of best fit and the limiting line.

Limited responses

- Some candidates misread coordinates or did not use a triangle that covered more than half of the drawn line.
- 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.

(iv) Comprehensive responses

- Candidates often substituted data from the gradient calculation in **(c)(iii)** into $y = mx + c$ to determine the y-intercept.
- A few candidates substituted a point directly from the line of best ft into $y = mx + c$ to determine the y-intercept.
- For the absolute uncertainty in the y-intercept, candidates initially determined the y-intercept of the limiting line by substituting a data point from the limiting line into y = mx + c using the gradient of the limiting line. Candidates then clearly found the difference between the y-intercept of the line of best fit and the y-intercept of the limiting line.

Limited responses

- Some candidates divided the y value by mx or calculated mx-y.
- Many candidates incorrectly read the y-intercept from the y-axis at $x = 2.46$ both for y-intercept and also the
- A small minority of candidates assumed that the fractional uncertainty in the gradient was the same as the fractional uncertainty in the y-intercept.

(d) (i) Comprehensive responses

- Many candidates were able to state that n was equal to the gradient value.
- Many candidates successfully rearranged the equation to determine γ substituting in the y-intercept correctly.
- Candidates considered the number of significant figures and gave their answers for n and γ to two or three significant figures.

Limited responses

- A number of candidates omitted '2' when using $10^{2\times y\text{-intercept}}$.

(ii) Comprehensive responses

- Most correctly calculated the percentage uncertainty by showing the absolute uncertainty in the gradient divided by the gradient.

Limited responses

- A few candidates used an uncertainty from the table.

(e) Comprehensive responses

- Clearly showed the method to determine v by correctly substituting in either the gradient and y-intercept into the relationship given in a $y = mx + c$ form or by substituting their values of n and γ into the given expression.

Limited responses

- Some candidates did not change the temperature to Kelvin.
- Did not show clear working and made inaccuracies in the calculation.