PHYSICS

Paper 9702/12
Multiple Choice

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

General comments

There was a wide spread of marks for this paper. Candidates found **Questions 22**, **29** and **35** the most accessible while **Question 28** was challenging for many candidates.

Comments on specific questions

Question 3

Many candidates did not notice that the question asked for the force that balanced the two forces.

Question 5

Although stronger candidates answered correctly, a large number of candidates did not recognise that the percentage error in the area of cross section was twice the percentage error in its diameter.

Question 6

Weaker candidates did not take account of the fact that the screen does not give a measure of distance, but of time, and often gave **D** as their answer.

Question 10

Only stronger candidates answered this question correctly. Errors were made by candidates not converting the mass to kilograms, not adding the $5.0\,\mathrm{ms^{-1}}$ to the $4.0\,\mathrm{ms^{-1}}$ and not using seconds.

Question 14

A large number of candidates answered **B** and only the strongest candidates gave the correct answer, **C**.

Question 20

All three of the incorrect options were chosen by candidates but stronger candidates were able to select the correct answer, **C**.

Question 21

Stronger candidates were able to answer correctly. These candidates registered the pattern of movement and often drew on the exam paper rather than just working this as a mental problem.

Question 27

Many candidates did not realise that the second order dark fringe will occur for a wavelength difference of 1.5.

Question 32

This questions proved challenging for many candidates. Options **C** and **D** were both popular incorrect choices, but the effect of the internal resistance is crucial in reducing the potential difference.

Questions 33 to 36

These were answered well but **Question 37** caused problems. If candidates sketched the circuit with the 2 ohm and 4 ohm resistors clearly in series they would have had no problem with finding **D** as the correct answer.

Question 39

This was only answered correctly by 44 per cent of candidates. Option **A** was too popular.

PHYSICS

Paper 9702/22
AS Level Structured Questions

Key messages

- Candidates should choose their words carefully, especially when using definitions and laws. The omission of a key word may prevent the candidate from being awarded credit.
- Candidates should be encouraged to read questions carefully to ensure that their answers are appropriate in context and no instructions are overlooked.
- It is important that candidates are familiar with the requirements of command words used in questions. For example, in questions using the words 'state and explain', candidates should provide an explanation as part of their answer. The syllabus contains a glossary of command words.

General comments

Candidates were often able to recall the appropriate formulae but these these formulae were sometimes incorrectly applied. Practice applying formulae in unfamiliar contexts would give confidence to candidates to apply their understanding.

There was no evidence that candidates were short of time to finish their answers.

Comments on specific questions

Question 1

(a) Many candidates gave the correct answers. A number of candidates incorrectly indicated that power was a vector quantity.

(b) (i) Many candidates obtained the correct answer. A minority of candidates were unable to separate the horizontal motion, where the acceleration was zero, and the vertical motion, where there was acceleration of free fall.

(ii) The majority of candidates obtained the correct answer. Many candidates realised that it was appropriate to use equations representing uniformly accelerated motion. A common error was to use the value of the horizontal component of the velocity as the initial vertical component of the velocity. A few candidates used $g = 10\ \text{m s}^{-2}$ which is inappropriately rounded up to one significant figure. Candidates should instead use $g = 9.81\ \text{m s}^{-2}$ in their calculations.

(iii) The majority of candidates were not able to sketch both graphs correctly. Weaker candidates often sketched an incorrect acceleration against time graph that showed the acceleration increasing with time. Another common error was to draw the vertical displacement against time graph as a straight line from the origin.

(c) There were some well-prepared candidates who correctly stated that there would be no effect of the increased mass on the time taken for the ball to fall to the ground. These candidates correctly explained that this was because the acceleration would remain the same. A large number of candidates gave a correct statement of the effect on the time, but did not provide any explanation. A common misconception was that the ball would take less time to fall to the ground because of the greater weight.

Question 2

(**a) (i)** Successful candidates used precise wording to explain what is meant by *work done*. It is important that candidates understand that for work to be done, the force has to move (its point of application) and that the distance moved or displacement must be in the direction of the force (or have a component in the direction of the force).

(ii) The vast majority of candidates were able to explain that kinetic energy is the energy of an object due to its speed. Weaker candidates sometimes stated a formula on its own which was insufficient for credit.

(b) (i)1 This part of the question was very well answered. In 'show that' type questions, candidates should methodically write down each step in their calculation leading to their final answer. Well-presented calculations enable candidates to check that their solution is correct and clearly demonstrate that the answer they obtain is the value given in the question. A small number of candidates 'forgot' to square the speed value at the substitution stage. A few candidates made the error of squaring the difference in the speeds.

(i)2 This question was well answered by the majority of candidates. A small number of candidates used the correct symbol formula, but then substituted the incorrect distance of 20 m along the circumference instead of the height. Some candidates wrongly assumed that there wasn't a resistive force acting on the carriage and so inappropriately equated the gain in gravitational potential energy to the loss in kinetic energy.

(ii) This question well answered by the majority of candidates. A small minority wrongly thought that the distance along the circumference would be equal to the length of the hypotenuse of a right-angled triangle with two sides of length 13 m.

(iii) A significant number of candidates were able to link the work done against the resistive force to the difference between the change in kinetic energy and the change in gravitational potential energy. There were many incorrect answers that attempted to determine an acceleration for the motion using the equations that represent uniformly accelerated motion in a straight line. This was inappropriate because the path of the carriage was not straight.

(iv) The more able candidates were able to provide a description that was awarded credit. The linear momentum was often described as decreasing without any reference being made to the change in direction.

(v) The majority of candidates did not recognise that the momenta at positions **X** and **Y** were in different directions. The change in direction needed to be taken into account when calculating the change in momentum. The candidates were required to read the question carefully; the magnitude of the change in momentum is not the same as the change in magnitude of the momentum.

Question 3

(a) (i) Most candidates gave a correct definition. Some statements were not given credit as the wording was not equivalent to 'force divided by cross-sectional area'. For example, stating the force 'on' or 'into' or 'by' cross-sectional area was not accepted as this wording does not give a clear relation between the two quantities.

(ii) There were many good answers. It was important that the candidates made reference to the 'original' length as part of the definition.

(b) (i) There were many answers that correctly suggested using a micrometer screw gauge to measure the diameter. Only the more able candidates described the need to take repeated measurements in different places along the wire.

(ii) The formula for the Young modulus of the material of a wire was stated correctly by many candidates and most candidates went on to calculate the correct answer. The most common error was to omit the conversion of the units of extension from millimetres to metres.

(iii) Only the stronger candidates were able to correctly calculate the increase in stored energy from the area under the graph. Many candidates could state the correct symbol equation, but then made errors when applying it to the question.

(c) Many candidates did not recognise that the gradient of the force against extension graph was proportional to the cross-sectional area divided by the length. Consequently, many drew a straight line through the origin with an incorrect gradient.

Question 4

(a) Many candidates gained credit for stating that the progressive waves needed to have the same frequency. Most candidates also understood that these waves needed to be travelling in opposite directions, although some candidates did not state that these waves must also overlap.

(b) (i) The vast majority of candidates were able to calculate the correct frequency.

(ii) Most candidates were able to calculate the correct time period of the sound wave. However, only a minority of candidates could then link the time period to the trace shown on the screen in order to determine the time-base setting.

(iii) Most candidates recognised that the new trace would have an unchanged time period. Candidates were less successful at drawing the correct amplitude of the new trace. A common mistake was to draw the new trace with an amplitude that was a half or a quarter of the original amplitude.

(c) (i) The distance between the two levels was calculated by a significant number of candidates. Other candidates did not appreciate how the wavelength was related to the positions of the two levels.

(ii) The majority of candidates did not realise that a node was produced at the water level when resonance occurs.

(iii) Many candidates found this question challenging**.** Although stronger candidates were often able to gain partial or full credit here, the majority of candidates either had difficulty determining the volume of water between levels **A** and **B** or made a power-of-ten error due to not converting units. Some candidates made no attempt at an answer.

Question 5

(a) A large number of candidates knew part or all of Kirchhoff's second law. It is important that candidates explicitly refer to the sum of the e.m.f.s and the p.d.s. Some candidates gave statements that were ambiguous. A significant majority of candidates did not make reference to a closed circuit or a loop of a circuit.

(b) (i)1 Most answers did not apply Kirchhoff's second law to the appropriate loop in the circuit. Some candidates wrongly thought that the p.d. across the 4.0 Ω resistor was zero and so deduced that the current in the circuit must also be zero.

(i)2 Most candidates had difficulty applying Kirchhoff's second law to this part of the question.

(ii) The majority of candidates realised which equation to use from the formula sheet. However, errors were often made when performing the necessary algebraic manipulation to calculate the required ratio of the average drift speeds. A small number of candidates wrongly thought that the two resistors had different currents.

(iii) Only the most able candidates recognised that increasing the total resistance of the circuit would lead to a reduction in the current and therefore a reduction in the power transformed by each of the batteries. The majority of candidates had difficulty explaining this effect.

Question 6

(a) Many candidates stated that the number of neutrons would decrease, but did not make it clear that there would be a decrease of one neutron. A significant number of candidates thought that there would be no change to the number of neutrons.

(b) The calculation of the current in amperes was reasonably well done, although an error was often made at the very end of the calculation when converting the units of the current from amperes to picoamperes.

(c) Only a small minority of candidates knew that the energy available from the decay is shared between the beta particle and an antineutrino. Others thought that the total energy released by the decay varied over a wide range.

PHYSICS

Paper 9702/33
Advanced Practical Skills 1

Key messages

- Candidates need to understand how to choose the correct number of significant figures to give for a calculated quantity. This should be the same as, or one more than, the number of significant figures in the measurement used in the calculation. (If more than one measurement is involved, this rule should be applied to the one with the fewest significant figures.)

  For example, when calculating $\frac{1}{L}$ using L values measured to the nearest mm:

L (cm)	$\frac{1}{L}$ (cm^{-1})
8.6	0.12 (or 0.116)
27.9	0.0358 (or 0.03584)

- If the only measurement in a calculation is an integer, such as a number n of resistors, significant figures don't apply because it is an exact value. The calculated value can have any convenient precision so it is best to choose one to give an accurate plotting position on a graph:

n	$\frac{1}{n}$
2	0.5
7	0.143 (not 0.1)
8	0.125 (not 0.1)

General comments

There was considerable variation in the standard of the candidates' work, but there were some very strong performances. Most calculations were carried out accurately, usually including correct rounding of the final values.

There was no evidence that Centres had any difficulties in providing the equipment required for use by the candidates. Help from supervisors was rarely necessary and where it was provided, Centres gave clear details of the assistance given.

Candidates did not seem to be short of time and both questions were fully answered by almost all candidates.

Comments on specific questions

Question 1

In this question, candidates were asked to investigate an electrical circuit. Most successfully set up the circuit correctly and took the required readings.

(a) Most candidates recorded a value for L_0 in the expected range, although in a few cases the unit was missing.

(b) Most candidates recorded a value for L less than L_0.

(c) Nearly all candidates recorded six or seven sets of values of n and L in a neat table without any assistance from the supervisor. In a few cases full credit could not be given because each increase in n did not produce an increase in L.

Good candidates included the highest and lowest values for n (8 and 2).

Most candidates gave correct column headings and units. A few gave the unit for n as Ω (rather than no unit).

In most cases measurements of L were correctly recorded to the nearest mm.

The calculated values of $\frac{1}{L}$ were usually correct, although there were some rounding errors and many cases of incorrect significant figures.

(d) (i) Many graphs were drawn to a very good standard with accurate and clear plotting of the correct quantities and good use of the available grid area.

Scales were usually simple so it was easy to avoid mistakes when reading coordinates off the grid. Some candidates chose to label their $\frac{1}{n}$ axis with fraction values $\left(\frac{1}{2}, \frac{1}{3}, \frac{1}{4}, etc.\right)$ giving an incorrect (non-linear) scale.

In some cases the points were drawn using dots that were too large. The clearest graphs used small crosses.

The quality of the candidates' work was judged by the scatter of points about a straight line trend and in the majority of cases this was good.

(ii) Many candidates drew good best fit lines with a balanced distribution of points about a straight line trend and in the majority of cases this was good.

(iii) Nearly all candidates knew how to find the gradient and intercept of their line. Most carried out the procedure accurately and showed their working clearly. However, some candidates used a triangle which was too small when finding the gradient. The intercept value could often be read directly off the $\frac{1}{L}$ axis as the $\frac{1}{n}$ axis usually started at zero.

(e) Most candidates recognised that a was equal to the value of the gradient and b was equal to the intercept (as calculated in **(d)(iii)**). Values of a given to one significant figure were not accepted.

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

Question 2

In this question candidates were required to investigate the change in size of a water drop between two transparent plates as the plate spacing was varied.

(a) When measuring the diameters of the wires, candidates sometimes had difficulty in recording their readings from a micrometer. Most micrometers give a reading to the nearest 0.01 mm and so the diameters should have been given for example, as 0.35 mm and 0.69 mm.

(b) Nearly all candidates gave a sensible value for the width of the water drop and very few omitted a unit.

(c) The graph grid used to measure the water drop had a 2 mm grid and so the uncertainty was at least 2 mm (at least half a division at each side). With a water drop size often as small as 5 mm, this resulted in a large percentage uncertainty.

(d) The strongest candidates recorded several width measurements leading to a mean value for the new size of the water drop.

(e) All candidates recorded values for w for the second water drop and in most cases the size was large, as expected.

(f) (i) The calculation of k involved the careful manipulation of the measured values, and nearly all candidates carried this out well.

(ii) When discussing the number of significant figures given for k, the strongest candidates explained its dependence on the significant figures of their d and w values.

(iii) Discussion of whether the analysis in **(ii)** supported the suggested relationship often lacked detail. Many candidates merely pointed out that the two k values were too far apart and did not suggest what difference would be acceptable in this experiment where w has such a large percentage uncertainty.

(g) The strongest candidates identified the major problems associated with carrying out this particular experiment – the low precision in w (due to the graph grid) and the possibility of parallax error when measuring w (due to the distance between the graph paper and the water drop). Using graph paper with smaller divisions or measuring with a ruler was often suggested to improve precision. There were very few valid suggestions for dealing with the parallax other than viewing from directly above (which could have been done anyway). The strongest candidates sensibly suggested reducing the distance between the graph and the water drop by marking the grid on the glass surface rather than having the grid underneath it.

There were many clear descriptions of the difficulty with seeing the edges of a colourless liquid and the need to colour the water.

The other point that came up frequently was the use of masses on the top glass sheet to provide the same force on the wires in each test.

In many cases, candidates were worried that the liquid dropper did not produce a consistent drop size but this was not relevant in this experiment.

PHYSICS

Paper 9702/42
A Level Structured Questions

Key messages

- Candidates should be reminded to use the data in the question as guidance for the expected number of significant figures in their answer. When data is given to 3 s.f. the answer will be expected to be accurate to 3 s.f. Hence candidates should work to at least 4 s.f. in mid-stage calculations.
- Candidates should also have an idea of the magnitude of the expected answer or when their answer is unreasonable. They should therefore have an idea of when they may have made a mistake and look for obvious errors like powers of ten, forgetting to square, forgetting to square root.

General comments

There was a wide range of ability of candidate taking the examination. There were many well-presented calculations and qualitative answers. However, the difference between well-prepared candidates and those who were not was obvious. These candidates would benefit from being more familiar with exam style questions in preparation for the exam.

Comments on specific questions

Question 1

(a) (i) Many candidates gave an answer to the question "explain what is meant by a gravitational field" rather than addressing the significance of the field line. Of those that did focus on the line, many thought that one line could give an indication of field strength. Very few realised that they needed to discuss the force on a mass placed at a point on the line and even fewer indicated that the line gave the direction of that force.

(ii) Most responses here did not make reference to the pattern of the field lines, as directed in the question. In addition, many candidates thought that gravitational field strength and gravitational force are the same thing, by saying "the field lines are uniform so the gravitational force is the same everywhere".

(b) (i) This calculation was generally well performed but there were a significant number of power of ten errors due to not converting the radius from km into m. Another source of error was forgetting to square the radius. Both of these errors led to extremely large values of gravitational field strength which were not noticed by the candidates.

(ii) Many candidates were able to use all the formulae required here, or they could remember the relevant Kepler relationship. However, the majority of candidates made errors in using the height of the orbit or the radius of the Moon instead of the total distance from the centre of the Moon to the satellite.

Question 2

(a) This calculation was well answered. Most candidates could recall the relevant equation.

(b) (i) The calculation of the volume here was well carried out. Most candidates used the equation of state once more rather than the fact that the volume is proportional to the absolute temperature at constant pressure. Errors were generally due to either use of the change in temperature rather than the final temperature or giving the answer to too few significant figures.

(ii) There was much confusion between internal energy and thermal energy, with many candidates obtaining a correct answer but then calling it the thermal energy and adding on an amount for work done as well. Only a minority of candidates followed the instruction to explain their reasoning by making it clear that for an ideal gas, the change in internal energy is equal to the increase in kinetic energy of particles.

(c) (i) Although there were a number of correct answers here, a common error was to use the new volume rather than the change in volume, which is incorrect physics.

(ii) Here candidates needed to recognise the sign of the work done and to realise that the value calculated in **(i)** was the work done by the gas. The answer to **(i)** therefore had to be added to the answer to **(b)(ii)** to apply the First Law of Thermodynamics correctly. Where the two answers had very different orders of magnitude, this addition had to be clearly shown to allow for credit to be awarded for any correct working.

Question 3

(a) Many candidates knew the circular shape of this graph. However, those who had not seen it before often guessed and often drew sinusoidal curves.

(b) Candidates knew the force would increase as the angle increased but did not know the detail of the shape of the curve here. Only a minority drew a line that indicated a realisation that the shape of the line is the first quadrant of a sine curve.

(c) This was well answered with many candidates showing the correct time period and amplitude.

(d) Many responses showed the correct relative positioning of the three nuclides required here. However, quite a few candidates placed the nuclides on the fusion side of the peak.

Question 4

(a) A significant minority of candidates gave a definition of natural frequency in terms of resonance, apparently not realising that such reasoning is cyclic and not possible. Resonance itself is defined in terms of natural frequency and a definition cannot work both ways.

(b) (i) A surprising number of candidates said the effect shown was damping.

(ii) The vast majority of candidates seemed to think that they had information about how the amplitude of the oscillation was varying with time. The majority of candidates concluded that the oscillation was damped, but only a small number gave a correct justification for this using the information that was actually available to them in the question (i.e. the shape of the amplitude – frequency graph).

(c) Many candidates were not able to state a useful example of resonance. A significant number of candidates incorrectly thought resonance was used in car suspension systems or car braking or that a useful application was the destruction of buildings during earthquakes. Candidates who had given "damping" as their answer to **(b)(i)** were credited in **(c)** for a correct useful application of damping rather than resonance.

Question 5

(a) Stronger candidates responded well here. However, a significant number used about half of their response to explain the production of ultrasound, rather than the use of ultrasound.

(b) (i) Most candidates were able to provide an accurate definition.

(ii) Many responses here referred to the amount of reflection at the boundary. While an answer of "very small" gained partial credit, an answer of "large" could not be credited. Candidates needed to realise the maximum value of the intensity reflection coefficient is, in fact, 1.

Question 6

(a) This was generally well answered, but some candidates gave 3- or 5-bit numbers rather than the 4-bits asked for in the question.

(b) Most candidates realised that the output voltage is stepped with a step width of 0.25 ms. Unfortunately, a significant minority of candidates contradicted an otherwise good answer by also drawing a curved line on their axes. Some candidates did not have the steps beginning at the correct times and were 0.25 ms too early, or 0.125 ms too early. Finally, a non-integer sampled value will always be rounded down for the 4-bit digital number and hence also the final output.

Question 7

(a) Most candidates were able to gain some credit here for the meaning of electric potential. However, the ratio of work done per unit charge was not clear in many responses.

(b) (i) Only a minority of candidates gave a correct explanation for why the two charges are of the same sign, in terms of the sign of the potential due to both being positive.

(ii)1 This part proved very challenging and was generally only well answered by stronger candidates. Many candidates discussed potential rather than speed.

(ii)2 Most candidates started with the correct formula but then used an incorrect potential or p.d. in carrying out the calculation.

Question 8

(a) (i) The meaning of infinite bandwidth was not well understood.

(ii) Candidates needed to make it clear here that there is no time delay between a **change** in the input and the subsequent **change** in the output.

(b) (i) There were many correct answers here. However, quite a few candidates reversed the potential divider and produced the incorrect value of 533 Ω.

(ii) Only a minority of candidates realised that the circuit is a comparator, with no feedback, and so the output will always by saturated, at ±9 V, with the switchover occurring at R_T.

(iii) Some candidates knew the correct symbol and direction of the diode but did not gain credit as it was not connected between V_{OUT} and earth.

Question 9

(a) Whilst many answers were correct, some candidates did not know which two faces the Hall voltage is developed between. An adequate description was needed in terms of the force on the electrons or the direction of movement of the electrons before credit for the positive face was gained.

(b) (i) Many candidates could not identify the distance 't' in the formula from the letters in the diagram.

(ii) The number of electrons was not sufficient here. It needed to be free electons or charge carriers and there also needed to be reference to "per unit volume".

(iii) Most candidates automatically thought the polarity would reverse here, without thinking it through in stages.

Question 10

(a) (i) The definition of magnetic flux was not well known. It is not the number of field lines passing through an area. It is also important that the area and the lines are perpendicular, or that the sin of the angle between the lines of flux and the area is used.

(ii) Most candidates gained full credit for the statement of Faraday's Law.

(b) Whilst the correct formula was known by many, errors were made from a combination of one or more of: not multiplying the change of flux by 2, forgetting the number of turns, not converting from milliseconds into seconds.

(c) Many candidates gave answers that attempted to describe how/why an e.m.f. is induced in coil C, rather than answering the question which asked them to describe the e.m.f. that is induced.

Question 11

Both parts of this question about band theory were answered well by candidates who were well prepared and knew their bookwork, but were answered poorly by those who did not.

(a) This proved to be the more challenging of the two parts, with many candidates thinking that the forbidden band in metals is so large that electrons are unable to jump it even with extra energy, rather than non-existent. Only a small number of candidates correctly linked the increased resistance to the increase in lattice vibrations of the metal atoms. Many candidates gave answers that implied that the lattice is initially stationary and only starts moving when the temperature is increased.

(b) Most candidates realised that electrons jump to the conduction band. The absorption of photons by electrons in the valence band was less well known, and the creation of holes in the valence band in the process was only well understood by stronger candidates. Photons were often not mentioned by name at all in the answers. For the final credit, candidates had to link decreased resistance with an increase in the number of charge carriers.

Question 12

(a) Many candidates were able to successfully gain full credit by giving two of the four possible explanations for the blurring of the image.

(b) (i) This calculation was well completed by many candidates, but there were often power of ten errors due to not converting the thickness into cm, or incorrectly converting the linear attenuation coefficient into mm^{-1}.

(ii) A number of candidates did not attempt this question at all.

Question 13

(a) (i) This definition was well known by candidates.

(ii) This required candidates to use a correct starting equation ($x = x_0 e^{-\lambda t}$) in one of its forms (either in terms of *x*, or of *N*, or of *A*). The equating of *x* with $\frac{x_0}{2}$ at time $t = t_{\frac{1}{2}}$ needed to be clear, with clear algebra, then showing how this leads to the required formula. Attention to the subscripts was vital here.

(b) This was a challenging calculation that stronger candidates were able to work their way through. Partial credit was available for the second stage of the calculation once the activity of the whole at the start had been incorrectly found. The most common incorrect approach was to try to compare the 3.8×10^4 figure directly with the 1.2 figure, without accounting for the 36 hours of decay in between them.

PHYSICS

Paper 9702/52
Planning, Analysis and Evaluation

Key messages

- Candidates should be encouraged to read the questions carefully before answering them to understand what is required.
- In **Question 1**, candidates' responses should include detailed explanations of experimental procedures such as how to control variables, how to take measurements and how to analyse the data.
- Graphical work should be done carefully and checked. Candidates should use a sharp pencil when plotting data points and a clear 30 cm ruler when drawing the line of best fit and the worst acceptable line. Care is also needed when reading information from the graph.
- The numerical answers towards the end of **Question 2** require candidates to show all their working, particularly when determining uncertainties. 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 over a period of time with a "hands-on" approach.

General comments

All candidates completed the paper and there was no evidence of candidates being short of time. The majority of candidates wrote clearly. There was a full range of marks for the paper with candidates usually score more highly on **Question 2** than **Question 1**.

In **Question 1**, the methods that candidates described often lacked detail and failed to mention the appropriate measurements. Candidates should think carefully about the experiment following the points given on the question paper and should think through how they would perform the experiment in the laboratory. Only the strongest candidates answered the analysis section well.

In **Question 2**, graphs were well drawn with points and error bars easily identifiable. Candidates should be advised that the presentation of mathematical working requires a clear statement of the equation used with correct substitution of numbers, including the power of ten. At all stages, candidates must keep in mind the unit of each answer. Stronger candidates set out their working in a logical and readable manner.

Comments on specific questions

Question 1

Candidates were required to investigate how the extension *e* of an elastic cord depends on the diameter *d* of the cord when a force is applied. They were required to test the relationship of the given equation between the extension *e* and diameter *d* of the cord and to find the value of Young's modulus *E*.

The question was based on a familiar topic to candidates. Many candidates gave good answers on the method of data collection and many also gave relevant additional detail. The analysis of the data was often not strong as many candidates did not correctly rearrange the formula into the form $y = mx + c$, so graphs with incorrect axes were plotted. Candidates should be advised to read the question carefully before starting their answer.

The vast majority of candidates correctly identified the independent and dependent variables. Many candidates also identified the force *F* remaining constant. Only a small number of candidates used the incorrect term "control" rather than the correct term "constant". There was also credit available for stating that the original length was constant – the question stated that the cords were about 50 cm.

For data collection, credit was available for a clearly labelled diagram. Diagrams needed to be drawn of the set-up of the experiment and to include all the equipment that was to be used. There also needed to be clear indications of distances that were to be measured. In this question the minimum requirements to gain credit was a labelled cord and load with the cord clearly attached to a support, e.g. a stand and clamp or hook from the (labelled) ceiling. Some candidates used a newton-meter either without fully explaining its use or incorrectly positioning it. Some candidates gained credit for a horizontal set-up that utilised a pulley.

Further credit was available for the method of measuring the quantities. Appropriate measuring instruments needed to be stated. To obtain the value of extension, a ruler was required to measure both the unstretched and stretched length of the cord. Stronger candidates also explained how the extension was determined from the length measurements. The statement “the extension is measured by a ruler” was not sufficient for credit. It was essential that candidates stated the measurement of the original length of the cord as the given cords were only approximately 50 cm in length. The mark could also be obtained from a labelled ruler placed parallel and close to cord in the diagram with clearly marked indications of the lengths to measure.

The measurement of the diameter of the cords with a micrometer screw gauge was generally given. Additional credit was available for repeating the measurements of d along each cord and determining an average and also for determining the force. A significant number of candidates confused force with mass. If a balance was used to measure the mass of the load, then the mass needed to be multiplied by g to obtain the force.

In the analysis of data, the majority of candidates selected the correct axes for the graph but there was a very large proportion of candidates who incorrectly suggested plotting e against d or e against $\frac{1}{d}$. Credit was awarded for plotting an appropriate graph. Candidates needed to explain how the graph would confirm the suggested relationship. It required the words “relationship is valid if” and the word “straight” to describe the line “passing through the origin”. E needed to be expressed in terms of the gradient. There was also credit available for correctly relating the area of the cord to its diameter.

In the additional detail section, candidates should be encouraged to write their plans including appropriate detail. Too often answers lacked sufficient practical experience. Vague responses could not be credited. It was essential that candidates’ answers were relevant to the experiment in question rather than general text book rules for working in the laboratory.

Candidates needed to give a safety precaution relevant to the experiment and a reason for this choice. For example, “goggles are worn to avoid the cord hitting the eye”. Answers relating to a sand tray/cushion needed to be explained in terms of a falling load.

Question 2

The question required candidates to analyse data given for how the fringe spacing P, of light passing through a double slit is related to the wavelength λ of the light.

(a) Candidates were asked to determine an expression for the gradient from a graph of P against λ. This part was well answered.

(b) Completing the table was done well and the vast majority of candidates gained full credit. The most common mistake was inconsistency in significant figures. For example, 4.8 was written instead of 4.80.

(c) (i) Most of the stronger candidates answered fully correctly. A significant number of candidates drew large blobs for the plotted points and these could not be credited. Many candidates needed to take greater care over the accuracy of the error bars to ensure that the error bar was symmetrical.

(ii) Most candidates used a sharp pencil and a clear 30 cm ruler which covers all of the points. The best fit line was nearly always in range. The worst acceptable line was drawn well in general. Candidates should indicate the lines drawn clearly. Where a dashed line is used to represent the worst acceptable line, the dashed parts of the line should cross the error bars.

(iii) Most candidates clearly demonstrated the points that they used to calculate the gradient. However some candidates misread the coordinates or did not use a sensibly sized triangle. A small number of candidates chose points that did not lie on the lines. Candidates should be encouraged to read the quantities from the axes carefully and to pay attention to powers of ten and units. When determining the uncertainty in the gradient, candidates needed to show their working, including the coordinates that they used from the worst acceptable line.

(d) (i) Most candidates gained at least partial credit. The most common difficulty was giving an appropriate unit with the correct power of ten. The power or ten in the gradient value was often incorrect due to confusion with powers of ten and units on the graph axes. The unit of *s* was often missing or sometimes given as a mixture of mm and m, which was not acceptable. Direct substitution of numbers in the equation did not gain credit as the question specifically required the use of the gradient.

(ii) Candidates were required to find the percentage uncertainty in *s* by using the gradient and *D*, the distance from the slits to the screen. This was answered well by either adding percentage uncertainties or an appropriate maximum/minimum method. Stronger candidates showed their working clearly.

(e) The strongest candidates answered this question well. Candidates needed to give the correct substitution of numbers in a stated equation as well as a justification of the answer. Again, there was a power of ten error in this part which resulted in an answer that was incorrect by a factor of 1000. Candidates were allowed an error carried forward for a power of ten error from **(d)**. The answer for λ was often out of range. Again, stronger candidates showed their working clearly.

Many candidates added percentage uncertainties and then converted to the absolute uncertainty of λ. Maximum/minimum methods could also be credited. A significant number of candidates did not gain credit in the calculation as their working was poorly set out.