# PHYSICS

**Paper 9702/12**
**Multiple Choice**

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

## General comments

The paper spread the candidates over a wide range of marks. Candidates found **Questions 1**, **2**, **8**, **16**, **30**, **32** and **38** particularly accessible. **Questions 19**, **31** and **34** were more challenging to candidates.

Candidates must always check that an answer is possible. A power of ten error was common.

**Comments on specific questions**

**Question 5**

Some candidates incorrectly thought a micrometer would be suitable to measure a distance of 10 cm.

**Question 14**

There was an even spread of responses across all four possible answers. The use of a Pythagoras triangle gives the correct answer easily.

**Question 19**

Candidates found this question particularly challenging. Responses **A** and **B** were popular incorrect answers. The extra power required by the car on the slope is $mgh \sin 2 = 1400 \times 9.8 \times 25 \sin 2 = 12.2$ kW giving the answer 42 kW. Some candidates forgot to add on the initial 30 kW.

**Question 26**

This was answered correctly by many candidates.

**Question 28**

A popular incorrect answer was **B**, but this implies only two wavelengths between GH and P.

**Question 31**

This was poorly answered question. **A**, **B** and **C** were keys frequently chosen.

**Question 34**

Candidates found this question challenging.

# PHYSICS

**Paper 9702/22**
**AS Level Structured Questions**

## Key messages

- Candidates should be encouraged to use the standard symbols for the quantities that are given in the syllabus.
- Candidates should always give the subject when expressing a formula. If the subsequent working is incorrect, this will help to identify what was intended by the candidate.
- When answering ‘show that’ questions, it is essential that candidates clearly present each individual step of their calculation leading to their answer.

## General comments

There was a wide range of performance on the paper. Better performing candidates completed all questions and appeared to have sufficient time to complete the paper. Some weaker candidates did not answer all parts of all of the questions.

## Comments on specific questions

### Question 1

**(a)** Most candidates found this reasonably straightforward. A common error was to think that power and work were both vector quantities.

**(b) (i)** A significant minority of candidates inappropriately used the symbol *d* instead of $\rho$ to represent the density of the material. The value of *g* used in the calculation should have been $9.81\,\text{m}\,\text{s}^{-2}$ rather than $10\,\text{m}\,\text{s}^{-2}$ because it was inappropriate to substitute the value expressed to only one significant figure. Some candidates rounded up the values of the volume and the mass during the calculation rather than waiting until the final answer before rounding to two significant figures.

**(ii)** The vertical component of the tension in the cable was usually calculated correctly. Many candidates did not realise that they also needed to take into account the weight of the sphere in order to calculate the final upthrust.

**(iii)** This was answered well by most candidates. A small number of candidates incorrectly thought that the upthrust was due to the density of the material of the sphere being less than the density of the water.

### Question 2

**(a)** Most answers explicitly referred to the total momentum of the bodies remaining constant. In some answers, ‘total’ was omitted, which suggested the momentum of only one body within the system.

**(b) (i)** This part of the question was very well answered. Most candidates started by writing down the appropriate algebraic equation and then showed the full substitution of numerical values. It was incorrect to introduce an unexplained but convenient factor of 0.5 half way through the working to achieve the required answer. Similarly, it was insufficient to state an answer of $6 \times 0.08 = 0.48\,\text{J}$ without explaining where the value of 6 has come from.

**(ii)1** Most answers were only partially correct. Candidates could usually equate the momentum of the two blocks or state an expression for kinetic energy. Better performing candidates were then able to clearly show all the steps in the numerical calculation leading to the final answer.

**(ii)2** Most candidates answered correctly. A minority incorrectly thought that the kinetic energy would be equally shared between the two blocks so that the kinetic energy of block A would be 0.24 J. Others mistakenly calculated the kinetic energy of block B instead of the kinetic energy of block A.

**(iii)** Many candidates realised that the graph would start from the origin and have a decreasing gradient. Very few candidates understood that when the extension of the spring becomes zero the force on block A will become zero so that the gradient of the graph becomes zero. A common mistake was to assume that the momentum of the block decreases to zero as the force on the block decreases to zero.

**Question 3**

**(a)** The vast majority of definitions were correct. It was insufficient to state 'change in displacement by time' as it was unclear whether this meant 'divided by' or 'multiplied by'. A few candidates incorrectly stated 'change in displacement in a unit time'.

**(b) (i)** This part of the question was well answered by the better performing candidates. A significant number of weaker responses incorrectly thought that the car could not move without having a resultant force acting on it and therefore wrongly deduced that the car could not be in equilibrium. A small number of candidates misinterpreted the graph as showing the car's speed increasing as it moved up the slope.

**(ii)** Although there were many correct answers to this question, weaker responses tried to use the weight of the car and the angle of the slope to determine the component of the weight acting down the slope. This method of calculation was unsuccessful because the angle of the slope was not given in the question. The weakest responses simply stated the weight of the car as their answer.

**(iii)** Answers were generally good with clear and explicit working.

**(iv)** Candidates needed to calculate the new force exerted by the engine on the car and the new resistive force acting on the car. Often only one of these two forces was correct. The most common error was to think that the force exerted by the engine on the car was still 2000 N when it had in fact reduced to 1200 N.

**Question 4**

**(a)** Answers needed to be precise; it was insufficient to vaguely refer to an 'object' rather than to a 'source' or to an 'observer'. Some candidates stated that the source was moving but did not mention that it was moving relative to the observer. A common misconception was that the observed frequency depended on the distance between the source and the observer.

**(b) (i)** The majority of answers were correct. Some candidates copied down the correct algebraic formula from the formulae given but then confused the speed of the source with the speed of the wave when substituting these two values.

**(ii)** This was answered well by the better performing candidates. A common misconception was that the frequency of the sound heard by the observer would increase and then decrease. This misconception possibly came from the fact that the frequency heard was initially higher than 950 Hz and then became lower than 950 Hz.

**Question 5**

**(a)** A number of candidates incorrectly stated that the electric field is directed to the left from point B to point A. Although the force on the electron is the left, the direction of the electric field must be to the right because the electron is negatively charged. Answers that vaguely stated that the electric field acts from positive to negative could not be credited.

**(b)** This part of the question was generally well answered. Some candidates wrote down the correct algebraic equation but then did not square the value of the initial speed at the substitution stage. Another common error was to do an interim calculation of the time taken for the electron to move from point A to point B as $0.02 / 1.5 \times 10^7$, which wrongly assumes that the speed of the electron remains constant.

**(c)** Some candidates attempted to use $E = V / d$ and incorrectly assumed that the symbol '*V*' in this equation represented the initial velocity of the electron.

**(d)** Clearer answers showed straight line graphs drawn with a ruler. The correct line needed to show clear intercepts at the *v*-axis and at the *t*-axis.

**Question 6**

**(a)** The first step in the derivation was to write down an equation showing that the total current is equal to the sum of the individual currents in each resistor; this step was sometimes omitted. The best answers presented all of the steps of the derivation in a clear and logical order. Weaker answers often had poorly set out working and expressions that were written without a subject.

**(b) (i)** The question specifically asked for an explanation that considers energy. Many answers mentioned 'lost volts' across the internal resistance but did not give an explanation in terms of energy transfer.

**(ii)** The energy transformed was usually calculated correctly; sometimes a power-of-ten error was made in the value of the charge. Many candidates also correctly calculated the number of electrons that pass through the battery.

**(iii)** The rearrangement of the equation for the combined resistance of the resistors in parallel caused difficulties for some candidates. A common wrong answer was 0.125 Ω, which is the reciprocal of the correct answer.

**(iv)** Most candidates stated the relevant power formula correctly. For the numerical calculation, some candidates incorrectly assumed that the potential difference across the two external resistors was 6.0 V.

**(v)** In this question, candidates needed to make it clear in their explanation that they were referring to total resistance. Simply referring to 'resistance' was too ambiguous as it could mean either the resistance of X or the combined resistance of the resistors in parallel or the total resistance of the entire circuit.

**Question 7**

**(a)** Most candidates answered this correctly. A small number of candidates did not read the question carefully and stated the number of protons and the number of neutrons for the daughter nucleus instead of for the parent nucleus.

**(b)** This question was generally well answered; sometimes a power-of-ten error was made in the value of the wavelength.

**(c)** The most common method of beam separation was to use an electric field. The question clearly specified that the method used should produce a beam of $\alpha$-particles and a beam of $\gamma$-radiation. Therefore, it was incorrect to explain the use of an absorber to remove the $\alpha$-particles.

**(d)** The conversion of the units of energy from eV to J was challenging for many candidates.

# PHYSICS

**Paper 9702/33**
**Advanced Practical Skills 1**

## Key messages

### Significant figures

Candidates often confuse the number of significant figures in a value with the number of decimal places to which it is presented.

For example, 12.7 mm can be written as 1.27 cm or 0.0127 m. All three have exactly the same precision because they have three significant figures, even though the number of decimal places varies.

A calculated value cannot be more precise than the least precise measurement used in the calculation, so the answer must be rounded to the same number of significant figures (or perhaps one more) as this measurement.

For example, the volume of a strip of wood 1.5 cm square and 3 m long is 1.5 cm × 1.5 cm × 3 m. The answer is 0.000675 $m^3$ but this must be rounded to no more than two significant figures (0.00068 $m^3$) because the length is only given to one significant figure.

### Apparatus

The springs used in **Question 1** are specified in the Confidential Instructions. The correct spring constant is particularly important as it determines the range of measurements available, so the use of a different type of spring may put the candidate at a disadvantage. If a Centre wants to use an alternative spring they should contact Cambridge to check its suitability.

Centres should not provide measuring equipment (e.g. Vernier callipers) unless it is listed in the Confidential Instructions.

If a spring balance (calibrated in grams) is provided instead of a Newton-meter, the candidate must be instructed how to convert the reading to a value in newtons.

## General comments

The general standard of the work done by the candidates was good, with many excellent scripts.

Most calculations were carried out accurately, including correct rounding of the final values.

There were very few reports of candidates needing help with setting up the apparatus. Supervisors are reminded that under no circumstances should help be given with the recording of results, graphical work or analysis.

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

**Comments on specific questions**

**Question 1**

In this question, candidates were asked to investigate the forces on a wooden strip in equilibrium. Candidates from many Centres had been prepared well in the techniques needed.

**Successful collection of data**

**(a) (iii)** All candidates recorded initial values for $l_1$ and $l_2$. A few omitted the unit and in a very small number of cases the relative sizes were not as expected.

**(b) (iii)** Most candidates recorded a value for the total mass *m* that was in the expected range.

**(c)** In cases where a very stiff spring had been used, the limited range of values sometimes resulted in no clear trend.

**Range and distribution of data**

**(c)** Having started with about half the washers on the hook, candidates were expected to include measurements both above and below this mass. Many candidates did this; some did not go near enough to the maximum mass available.

**Quality of data**

**(d) (i)** Most candidates were credited for the quality of their results. This was judged by the scatter about a straight line of the points on their graph.

**Presentation of data and observations**

**Table**

**(c)** Most tables were neat and clear.

Column headings were always included and usually included the correct unit; some candidates put units in the body of the table.

The majority of candidates recorded all their measured values of length to the nearest millimetre; some candidates missed the millimetre figure out if it was zero (e.g. 7 instead of 7.0 cm). In a very few cases, a spurious zero was added to the end of every measurement (e.g. 7.30, 8.10 etc.).

**Graph**

**(d) (i)** For their graph of $(l_2–l_1)$ against *m*, most candidates used simple scales, but in many cases the choice led to the points occupying less than half the grid in the $(l_2–l_1)$ direction so the scale could have been doubled.

Most candidates plotted their tabulated readings accurately. Candidates from a few Centres plotted their points as large dots, making it difficult to judge the points’ coordinates.

**(d) (ii)** Best-fit lines were generally chosen well and drawn clearly, without any kinks or changes of gradient.

**Interpretation of graph**

**(d) (iii)** Most candidates had been well prepared in finding the gradient and intercept of their line; weaker responses used too small a triangle when determining the gradient.

For the intercept, there were some mistakes where the intercept value was read directly even though the graph had a false origin.

**Drawing conclusions**

**(e)** Most candidates recognised that *a* was equal to the value of the gradient and *b* was equal to the value of the intercept. A few candidates gave one of the values to only one significant figure and some omitted a unit.

**(f)** In most cases the calculation of *k* was carried out correctly. Some candidates made mistakes when changing the unit for *a* from $\text{cm g}^{-1}$ to $\text{m kg}^{-1}$.

The number of significant figures given for *k* was generally correct; there were some rounding mistakes.

**Question 2**

In this question, candidates were required to investigate the friction between a plastic pipe and string sliding over it.

**Successful collection of data**

**(a) (ii)** The first pipe diameter was recorded to the nearest millimetre in most cases but often there were no repeated readings.

**(c) (iii)** *F* was usually correctly recorded to the nearest 0.1 N; repeated measurements were frequently omitted.

**(e)** All candidates recorded data for the second pipe.

**Estimating uncertainties**

**(d)** *F* was measured using a Newton-meter with a precision of 0.1N; better responses recognised that the uncertainty in the measurement was much greater than this due to the variation found during the measurement and in repeated measurements.

Several candidates used the alternative approach of looking at the scatter of repeated measurements in terms of half the range of their values and expressing this as a percentage of *F*.

**Quality**

**(e)** Quality of results was judged by the values of *F*; both had to be at least greater than the weight being lifted.

**Display of calculation and reasoning**

**(b) (ii)** Calculation of *W* and rounding of the value was usually correct.

**(iii)** Better performing candidates gave a complete explanation for the choice of significant figures for *W*. Many did not mention the significant figures in *g* and others did not understand the topic.

**(f) (i)** The great majority of candidates were able to calculate *k* values correctly from the two sets of data; some gave their answers to only one significant figure.

**Analysis and conclusions**

**(f) (ii)** The comparison of the two values of *k* and the evaluation of the suggested relationship was done by better performing candidates, with a clear criterion against which the comparison was judged. The terminology used was not always accurate; 'percentage uncertainty in *k*' was frequently used when referring to the percentage difference between the two *k* values that had been calculated. Many candidates omitted a stated test criterion, just saying that 'the *k* values were close'.

**Evaluation**

**(g) (i)** and **(ii)**

Those candidates who thought carefully about this section and gave clear and complete descriptions performed well.

The majority of candidates recognised that two sets of data were insufficient to draw a valid conclusion and went on to suggest taking more readings and plotting a graph.

The first area of measurement difficulty was the pipe diameter. The pipe should have been cut at right angles to its axis so parallax was not a problem but if the cross section was not circular there would be no single value for diameter. The precision of the ruler was only 1 mm and so the uncertainty in *D* was large, especially for the smaller diameter pipe. Both of these difficulties were described by some candidates who usually went on to suggest using a Vernier or digital calliper as an improvement.

The second area of measurement difficulty was the force *F*. This varied as the hook was being pulled down and could only be viewed for the short time before the hook arrived at the bench. Many candidates gave parallax as the cause of difficulty; this was not the most significant problem, which was in estimating an average value for the reading. Many candidates suggested the use of recording images of the force scale and those who mentioned viewing the playback gained credit. Others suggested suspending increasing known weights to establish the force required.

Some candidates talked about the value of force at the moment when the mass left the bench; this was not what was required.

Many were concerned that the pipe tilted under load; only a few of these described the problem it caused (i.e. the string sliding off).

A table giving details of other acceptable limitations and potential improvements can be found in the published mark scheme.

# PHYSICS

**Paper 9702/42**
**A Level Structured Questions**

## Key messages

Candidates should be reminded to take care in drawing graphs. More attention was needed to ensure that the shape and any relevant numerical values was included. There were some instances of careless and rushed graphs.

Further work on ensuring relevant explanations are given would be beneficial. Many candidates were able to give correct answers for parts of questions but could not give explanations for their answers for further credit.

## General comments

It was clear that the majority of candidates had been well prepared for this examination. Calculations were usually clearly and logically presented. Candidates made good use of the time available and there was little, if any, evidence that candidates did not finish the paper in the given time.

## Comments on specific questions

### Question 1

**(a)** This definition was only well expressed by better performing candidates. It needed to be clear that there is a division, i.e. work done per unit mass. Many candidates stated, 'work done in bringing a unit mass', which did not gain full credit. A number of weaker responses stated, 'force per unit mass', the definition of gravitational field strength.

**(b) (i)** This was completed well with clear presentation by many candidates. Weaker responses found the mathematics of the fraction more challenging and tried to use numbers such as GM/4R – GM/R.

**(ii)** The most common errors here were not using the expression in **(b)(i)** and not multiplying the potential by the mass of the rocket. Other errors were power of ten errors and finding *R* by neglecting to multiply by three to find the distance from A to B.

### Question 2

**(a)** Candidates needed to make clear if there is an increase or decrease of internal energy when stating the meaning of the symbols used in the first law of thermodynamics. They also needed to clearly state the direction of the heat transfer and the work done. The response also needed to refer to the gas or the system.

**(b) (i)** This *show that* calculation of the increase in the internal energy of the gas was well answered. Many candidates were able to correctly apply $W = p\Delta V$.

**(ii)** The question required candidates to consider molecular energy. Many did not refer to internal energy, kinetic energy and potential energy. They answered by referring to macroscopic quantities such as pressure and volume instead.

**(iii)** There were some correct answers here, but many candidates added and subtracted any numbers from the question that were energy related, rather than correctly using the two changes in internal energy.

**(iv)** Many responses showed evidence of a fundamental misconception here. Candidates calculated the number of moles, n, using $pV = nRT$ and thought they had calculated the number of molecules and so stopped here.

**Question 3**

**(a)** Most candidates knew that the acceleration is proportional to the displacement and that these are in opposite directions for an object moving with simple harmonic motion; they did not always relate these to the given expression. Answers rarely stated that *k* and *m* are constants. Often the minus sign was related to the opposite directions.

**(b)** Most candidates were able to compare the expression to the general one for SHM and could get to the result given. Only a very few incorrectly quoted the formula by omitting the squaring of the amplitude.

**(c)** This calculation was well executed and there were many correct answers.

**(d)** Many candidates answered correctly but a significant number gave the final answer of the amplitude as 0.02 m. These answers were given to too few significant figures.

**(e)** The explanations given here for the more rapid decrease in the amplitude of the oscillations rarely gained maximum credit. One common misconception was the block being attracted to the magnets, but this force would be equal both sides and does not act in the same direction as the motion. Another was to state that the eddy currents oppose the motion, which misses out a number of stages in the logic. The question required the use of energy conservation in the answer and candidates needed to recognise that when the flux is cut by the block an e.m.f. is induced in the block, which must be stated before moving on to the induced current.

**Question 4**

Many answers either only described how ultrasound is used to form an image or wrote about the generation of ultrasound. An important point to note here was that the frequency of vibration generated is in the ultrasound range.

**Question 5**

**(a)** Most candidates were able to state three advantages of an optic fibre.

**(b)** Candidates who knew the formula here and knew how to use the formula did well. A few candidates substituted incorrect powers into the formula. In **(b)(ii)**, a comparison to 24 dB or $2.1 \times 10^{-5}$ W was expected.

**Question 6**

**(a)** There were some strong answers here. Credit could not be awarded when candidates made statements that did not refer to the field lines, for example following an inverse square law or being attractive/repulsive.

**(b) (i)** The majority of candidates were able to quote the correct formula for electric field strength but then did not apply it to the context of the question. They did not take the presence of two charges into account and carried out the calculation as if charge X was the only charge present. A few candidates answered by adding the two electric fields rather than subtracting them. A final error made here was to use an incorrect formula where the distance was not squared.

**(ii)** The sketch graphs drawn here often showed a misconception that the field strength was varying linearly with distance, rather than following an inverse square law. Another error was to ignore the fact that the direction of the electric field strength was reversing at the midpoint.

**(iii)** While some responses were excellent, many referred to just acceleration and then deceleration. These candidates had not realised that the magnitude of the acceleration was changing with distance.

**Question 7**

**(a)** Many good diagrams were drawn; often candidates did not mention that the wire is thin. In addition, the connections to the strain gauge needed to be clear and the wire should not have appeared to short circuit itself within the plastic envelope.

**(b) (i)** Only better performing candidates were able to complete this calculation. Some responses led to changes in resistance that were not of a sensible size leading to a change in length that was not on the provided graph. Weaker responses tried to use the resistivity formula rather than the potential divider formula (or ratios) here. Incorrect physics was often seen when the potential divider calculation used a resistance of 300 Ω, which is not correct once the strain gauge has been extended.

**(ii)** The explanations given here were often very good. The most common statement to miss was that the strain gauge would increase in resistance. Weaker responses tended to get the reverse argument, hence leading to led Y emitting light.

**Question 8**

**(a)** In this question, credit could not be given for answers using the word ‘field’. This needed to be explained as a region/area.

**(b) (i)** Only better performing candidates answered this correctly. Candidates needed to apply Fleming’s Left Hand Rule here, rather than looking at the diagram and deciding the direction of the field as being from left to right by observing the curve. The word ‘upwards’ was often seen. This was not precise enough and could not be credited.

**(ii)** Candidates needed to realise that the force was perpendicular to the velocity for circular motion, rather than the field being perpendicular to the velocity. In addition, the terms ‘motion’ and ‘speed’ were sometimes used instead of the term ‘velocity’. Common errors were to say that the speed was constant because the magnetic field strength was constant, or that the particle was travelling in a vacuum.

**(iii)** The stages leading to this expression were usually clearly shown in responses.

**(iv)** A significant number of responses showed that candidates were confused by the diameter of the path and the distance travelled during the semi-circular path and considered them to be the same. A number of candidates did not consider that the path was a semicircle, rather than a circle and were a factor of two out with their final expression. A final statement that the time was independent of the speed was required for full credit.

**Question 9**

**(a) (i)** Most responses referred to iron being magnetic, a conductor, or that iron will increase the magnetic field strength. Candidates were not aware that the iron increases the magnetic flux linkage.

**(ii)** Many candidates were able to explain that d.c. has constant flux so e.m.f. is not induced as there is no change in flux linkage. Some candidates did not refer to flux at all and gained no credit.

**(b) (i)** This calculation was completed well. Only a very small number of candidates misremembered the equation.

**(ii)** Better performing candidates were able to apply Faraday’s Law and use the fact that the gradient of a flux linkage graph gives the induced e.m.f. A very common error was to think the maximum flux linkage would be where the e.m.f. was also maximum.

**(c) (i)** Many candidates incorrectly used $P = V^2/R$ here and substituted in the peak value of p.d. in order to find the mean power and so did not gain any credit.

**(ii)** Many candidates draw a sketch that revealed they thought the shape would be like a fully rectified sine wave. Only a small number of candidates knew the peak power would be twice the mean power by drawing the peak of their graphs at 2.4 W. Most drew the peak at 1.2 W instead.

**Question 10**

**(a)** Many candidates could state what is meant by a photon. Some needed to make the link between the quantum of energy and electromagnetic radiation.

**(b) (i)** The fact that the re-emitted photons would travel in all directions was not well known by candidates.

**(ii)** Many candidates could not use the range of energies in the beam and the diagram of the energy levels in hydrogen to draw the correct electron transitions. More had the direction of the arrow as correct for an absorption spectrum.

**(iii)** A common error here was to use the maximum energy electron transition from the diagram rather than the maximum energy from the initial beam. A significant number of candidates did not convert the energy from electronvolts into joules.

**Question 11**

This was an area which would benefit from further focus. Many candidates stated that conductors have a forbidden band and that this is wider in conductors than in semiconductors. Some answers stated that electrons vibrate more vigorously when the temperature is increased. In addition, many candidates did not consider the effect of increased lattice vibration in a semiconductor. Often it was not made clear that moving charge carriers were current.

**Question 12**

**(a)** Many candidates knew that this was the energy needed to separate the nucleons in a nucleus; many did not state that this would be to an infinite separation. Some language used by candidates was not precise enough for credit, for example phrases such as ‘the energy needed to hold the nucleus together’, or terms such as ‘constituent particles’ in place of nucleons.

**(b) (i)** A number of candidates misunderstood this question. Some referred to mass instead of binding energy and some stated the binding energy of the thorium and helium would be equal to the binding energy of the uranium. Many just quoted ‘$E = mc^2$’. Some answers gave the binding energy before the reaction as greater than that afterwards.

**(ii)** These calculations were often completed well and with good presentation. Some candidates ignored the helium nucleus in **1**. Other candidates did not convert from atomic mass units into kilograms when calculating the energy released in the reaction in **2**.

**(iii)** Most candidates did not consider the other products of the reaction here and the fact that the helium and the thorium would have kinetic energy.

# PHYSICS

**Paper 9702/52**
**Planning, Analysis and Evaluation**

## Key messages

In planning questions, candidates' responses should include detailed explanations of experimental procedures such as control of variables, measurements to be taken and analysis of data.

Graphical work should be carefully attempted and checked. Candidates should use a sharp pencil when plotting data points and use 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.

Numerical answers 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 time constraints. The majority of the scripts were clearly written. It was evident that the higher scoring candidates had experienced a practical course where the skills required for this paper had been developed and practised over a period of time.

In **Question 1**, the methods that candidates described often lacked detail and did not mention the appropriate measurements. In this question there was a lot of irrelevant writing. It is advisable that candidates should think carefully about the experiment following the points given on the question paper and should imagine how they would perform the experiment in the laboratory.

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, leading to the correct answer. Better performing candidates set out their working in a logical and readable manner.

## Comments on specific questions

### Question 1

Candidates were required to investigate the speed *v* of a vehicle of mass *M* when a small ball is projected into the vehicle. They were required to test the relationship of the given equation between speed *v* and mass *M* and to find the value of the spring constant *k* from the results of the experiment.

Some candidates were confused by how to proceed with the laboratory experiment. One common misconception was with the significance of the quantity *M*, with some candidates taking it as being the mass of the vehicle plus the mass of the ball, while others used *M* as the mass of the ball itself. The question required candidates to determine the value of the spring constant *k* from the graph and not from a Hooke's Law experiment for the spring. Candidates should be advised to read the question carefully and then formulate a workable plan before starting their answer.

Initially candidates needed to identify the independent and dependent variables. Several candidates interchanged the two variables. Candidates should consider how the variables should be controlled. In this question candidates were expected to state explicitly that the compression of the spring *x* would be kept constant.

Diagrams needed to include the necessary pieces of apparatus set up as they would be used in the experiment. In this experiment a labelled spring was needed to be drawn horizontal and attached to a support.

Appropriate measuring instruments needed to be stated. Candidates needed to determine the velocity of the vehicle. Candidates needed to explain carefully their proposed method. Responses often included an explanation of how a time measurement could be made using a stopwatch or light gates connected to a timer. Better performing candidates indicated the position of the light gates in the diagram. These candidates indicated the length measured with a ruler that would be needed (distance between light gates or length of card interrupting the light gate) to determine the speed of the vehicle and an appropriate equation. Candidates also needed to explain how the compression of the spring and mass *M* of the vehicle would be measured. Some candidates suggested the use of motion sensors. The sensors needed to be placed in the correct position, shown in the diagram and a clear explanation of the determination of speed given.

Most candidates were able to analyse the data. The majority of candidates explained the graph that needed to be plotted but a few candidates did not realise that the question stated the function that needed to be plotted on the *y*-axis.

Most answers included an explanation of how the graph would confirm the suggested relationship. Better performing candidates included the words ‘relationship is valid if’ and ‘straight’ to describe the line. Some candidates gave the answer correctly in terms of the *y*-intercept.

Candidates should be encouraged to write their plans including appropriate detail. Some answers did not demonstrate sufficient practical experience for credit. It is essential that answers are relevant to the experiment in question rather than general rules for working in the laboratory.

A reason needed to be given as to why the safety precaution suggested was selected. For example, goggles are worn to avoid the ball or metal spring hitting the eye.

Stronger responses also referred to repeating the experiment for each mass to determine an average speed of vehicle, releasing the ball close to the vehicle, changing *M* by adding masses to the vehicle or changing the vehicle.

**Question 2**

The question required candidates to analyse data given for how the potential difference, *V*, across the resistor P is related to its resistance, *P*.

**(a)** Candidates were asked to determine an expression for the gradient and *y*-intercept from a graph of $1/V$ against $1/P$. A significant number of candidates answered incorrectly.

**(b)** Most errors in calculating values in the table were for the number of significant figures used rather than the numerical values. A large number of candidates made errors in the $1/V$ column. For the first two rows, as *V* was given to two significant figures, $1/V$ should be given to two or three significant figures; for the last four rows, as *V* was given to three significant figures, $1/V$ should be given to three or four significant figures. Candidates needed to be able to round correctly. The majority of candidates calculated the absolute uncertainties correctly.

**(c) (i)** The majority of candidates performed well for this part. The points and error bars were generally plotted correctly. A significant number of candidates drew large blobs for the plotted points. Candidates need to take greater care over the accuracy of the error bars and check to ensure that the error bar is symmetrical.

**(ii)** The drawing of the straight lines was much improved. Most candidates used a sharp pencil plus a clear 30 cm ruler, which covered all of the points. A few candidates joined the first plotted point to the last plotted point. This was not the best-fit line. Candidates should be encouraged to draw a line, which has a good balance of points about the line.

**(iii)** Most candidates clearly demonstrated the points that they used to calculate the gradient. Some candidates misread co-ordinates 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 quantities from the axes carefully; a large number of candidates ignored the $10^{-3}$ factor.

**(iv)** Candidates found determining the *y*-intercept challenging. Better responses showed good, clear working in the calculation of the *y*-intercept. The common mistake in calculating the uncertainty in the *y*-intercept was either using the same co-ordinates as the best–fit line (providing it was not the crossing point), or using the same gradient of the best–fit line. Some candidates read the value from a false origin.

**(d) (i)** Candidates were required to determine a value of the electromotive force *E* of the cell, by calculating the reciprocal of the *y*-intercept, and a value for the constant resistance *Q* using the gradient and the calculated value of *E* (or *y*-intercept). Most candidates were able to do this but a few candidates omitted the unit. Fewer candidates were able to give the calculated value of *Q* to two or three significant figures and the correct power or ten and the correct unit. Better performing candidates showed clear, logical working. These candidates usually stated the applicable equation, then substituted values for the known quantities leading to the answer.

**(ii)** Candidates were required to show clear working to determine the percentage uncertainty in *Q*. This was quite well answered by candidates who used the method of adding percentage uncertainties of the gradient and *E* (or *y*-intercept). Those candidates who attempted to calculate the maximum and minimum values for *Q* tended to make more mistakes by using incorrect combinations of maximum and minimum values.