PHYSICS

Paper 9702/11
Multiple Choice

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

General Comments

This multiple choice paper is set on just the AS part of the syllabus and, with 40 questions to be answered within the time limit of an hour, accurate and quick working is essential. Candidates must know that they should not spend too long on any one question. Many questions need written working if candidates are to maintain accuracy. There is plenty of space on the paper and candidates should make use of it.

One question, **Question 21**, was answered correctly by more than 80% of the candidates and four, **Questions 29**, **30**, **33** and **36,** were correctly answered by less than 20% of the candidates.

Comments on Specific Questions

Questions 1, **3**, **12**, **15**, **17**, **18**, **19**, **21**, **22**, **25**, **38** and **40** were correctly answered by 60% or more of the candidates. There was a large gap covering **Questions 26** to **37**. This indicates that the waves and electricity sections of the syllabus are less well understood than the rest of the syllabus.

Questions where there were many candidates making the same mistake were as follows.

Question 6

43% of candidates did not allow a longer time for the ball to return to the slope after its inelastic collision with the wall. The inelastic collision causes a loss of speed. There were another 24% who chose option **C**, which shows a deceleration much larger than the acceleration on the friction-free slope. The acceleration due to gravity should be constant.

Question 8

Candidates should remember that *g* is a constant. 41% thought **A** was correct and 32% thought **D** was correct.

Question 10

Only 29% knew that **C** was the definition of force; 59% incorrectly answered **A**.

Question 11

35% of candidates thought that **D** was the correct answer.

Question 24

All four options were more or less equally chosen, suggesting that many candidates guessed. Only 27% chose the correct answer.

Question 27

All four options were similarly popular here too. Candidates do need to know approximate values of wavelengths. That the (narrow) visible band of wavelengths is centred on green at 5.0×10^{-7} m is a useful figure to start with.

Question 28

21% were correct here. Cover up one slit and the wave amplitude is halved, so the intensity is one-quarter.

Question 29

Here only 16% gave correct answers. This does need care to see that both pipes will give a stationary wave.

Question 30

This seemed straightforward with answer **C** but it had only 17% choosing it. **A** and **B** were both popular. The phase difference between the waves from P and Q is constant along the line RS, so there can be no interference pattern along RS.

Question 32

This was another question with the four options more or less equally chosen. This suggests that many candidates guessed rather than using up time doing a proper analysis. 25% did get the correct answer.

Question 36

41% gave **D** as the correct answer instead of **B**. Candidates would benefit from additional support in understanding the difference between p.d. and e.m.f.

PHYSICS

Paper 9702/12
Multiple Choice

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

General Comments

This multiple choice paper is set on just the AS part of the syllabus and, with 40 questions to be answered within the time limit of an hour, accurate and quick working is essential. Candidates must know that they should not spend too long on any one question. Many questions need written working if candidates are to maintain accuracy. There is plenty of space on the paper and candidates should make use of it.

Only four questions were answered correctly by more than 80% of candidates and only two, **Questions 15** and **31**, had less than 25% of candidates obtaining the correct answer.

Comments on Specific Questions

Questions that produced more than 50% of correct responses were **Questions 2**, **3**, **4**, **5**, **6**, **7**, **8**, **11**, **13**, **14**, **16**, **17**, **18**, **19**, **20**, **22**, **24**, **27**, **29**, **30**, **32**, **33**, **36**, **37** and **40**.

Other questions where there was an unexpected outcome were as follows.

Question 1

This was answered correctly by only 43% of candidates; 39% thought that the electronvolt measured electric potential. Candidates should be advised that the eV is a unit of energy.

Question 9

Only 45% of candidates realised that, without knowing the mass of the ball, its acceleration cannot be determined.

Question 10

50% of candidates incorrectly thought that the truck would speed up at Y. Candidates should consider conservation of the total momentum of the truck and sand, rather than considering the truck in isolation.

Question 12

The subtraction of vectors always requires care to be taken. (It often produces surprising results, as with the acceleration of a body travelling in a circular path.)

Question 15

Many candidates forgot to add on the original 4 J here.

Questions 21 and **23**

With both of these questions, interpreting the graphs proved difficult.

Question 28

Many candidates did not realise that white light will produce a few fringes.

Question 31

This question was the most difficult, with only 16% correct. The direction of field lines is the direction of the force on a positive charge. So the answer is **A**, the charge being negative. **C** had 51% responses.

PHYSICS

Paper 9702/13
Multiple Choice

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

General Comments

This multiple choice paper is set on just the AS part of the syllabus and, with 40 questions to be answered within the time limit of an hour, accurate and quick working is essential. Candidates must know that they should not spend too long on any one question. Many questions need written working if candidates are to maintain accuracy. There is plenty of space on the paper and candidates should make use of it.

Six questions were answered correctly by more than 80% of candidates. At the other end of the scale, only **Questions 29**, **35** and **38** had less than 25% of candidates obtaining the correct answer.

Comments on Specific Questions

Questions that produced more than 50% of correct responses were **Questions 1**, **2**, **4**, **5**, **6**, **10**, **11**, **12**, **13**, **14**, **15**, **16**, **18**, **19**, **20**, **23**, **24**, **26**, **28**, **32**, **33**, **34**, **36**, **37**, **39** and **40**. Other questions where there was an unexpected outcome were as follows.

Question 3

Many candidates ignored the fact that the diameter of the wire is squared, giving an uncertainty of about 7% for this term.

Question 7

41% of candidates did not allow a longer time for the ball to return to the slope after its inelastic collision with the wall. The inelastic collision causes a loss of speed. There were another 19% who chose option **C**, which shows a deceleration much larger than the acceleration on the friction-free slope. The acceleration due to gravity should be constant.

Question 8

The stem of the question states that the body does reach terminal velocity, so the height from which it falls does not affect its terminal velocity. All the other statements do, but these each gained about 20% of choices made by candidates.

Question 9

Candidates need to remember that *g* is a constant. 24% thought **A** was correct and 27% thought **D** was correct.

Question 21

E is a constant for a particular type of steel, but 39% of candidates thought 2*E* was the correct answer, the same percentage as had the correct answer **B**.

Question 22

The first three options were more or less equally chosen, suggesting that many candidates guessed. Only 30% chose the correct answer.

Question 25

This was another question where the first three answers were almost equally chosen. Once the Young modulus equation is rearranged $\Delta l \propto l / l^2$ makes answer **B** clear.

Question 27

The correct answer here was given by 36%. Cover up one slit and the wave amplitude is halved, so the intensity is one-quarter.

Question 29

Only 23% realised that the interference pattern is only along XY (although there can be one along PQ, but that was not an option). **A** and **B** were both more popular choices. The phase difference between the waves from P and Q is constant along the line RS, so there can be no interference pattern along RS.

Question 30

Here there were only 33% correct answers. This does need care to see that both pipes will give a stationary wave.

Question 35

This question was the most difficult on the whole paper, with 14% of responses correct. Careful analysis is needed to sort out the correct response and this must be done by careful working—for which there is plenty of space.

Question 38

36% gave **D** as the answer instead of **B**. Candidates would benefit from additional support in understanding the difference between p.d. and e.m.f.

PHYSICS

Paper 9702/21
AS Structured Questions

Key Messages

- Many candidates would benefit from taking a moment to consider the numerical answers that they have obtained, especially as regards powers of ten. A quick check on whether an answer is 'reasonable' would allow candidates to detect errors in their working.

- Candidates should be encouraged not to 'round off' answers at intermediate stages of a calculation, as this can lead to inaccurate and inappropriate final answers.

- Candidates should be advised to use the data given on page 2 of the question paper. In particular, the use of the approximation $g = 10\,\text{m}\,\text{s}^{-2}$ should be discouraged.

- The application of knowledge of basic concepts to unfamiliar situations is often found to be difficult. Candidates who have difficulty would improve their performance if they spent time discussing and practising the application of basic concepts to new situations.

- Most candidates could improve their performance by learning the precise details of definitions and laws required by the syllabus. The wording of answers should relate to the question asked and a certain amount of precision is required at this level. A vague statement of the terms involved is generally not sufficient.

General Comments

There were few candidates who did not complete their answers to questions. There was no evidence amongst adequately prepared candidates of a shortage of time.

Candidates appeared to find some parts of all questions difficult. Responses did vary considerably with Centres.

Candidates should be encouraged to read carefully through any question before making any attempt with an answer. Generally the mark allocation indicates the required length and complexity of any answer. Candidates should be made aware of the need to give specific detail included in the question when asked to give explanations.

Comments on Specific Questions

Question 1

(a) Generally definitions were satisfactory. Candidates should be advised that where equations are given as definitions then all symbols should be defined.

(b) The great majority of statements did not answer the question that was asked. Candidates needed to read the question carefully and use the variation in the spacing of the molecules to explain the difference in the densities of solids, liquids and gases.

(c)

(i) A significant number of candidates obtained the correct answer. The weaker candidates had difficulty with the units and powers of ten.

(ii) Weaker candidates were able to gain partial credit for the equation for pressure. The more able candidates realised that the force required the weight of the slab and that maximum pressure is obtained with the smallest area.

Question 2

(a) The majority of candidates did not give enough detail in their definition. Candidates should be reminded that a precise definition is needed in order to obtain full credit.

(b)

(i) This was generally well answered by the well prepared candidates.

(ii) A significant number of candidates recognised that the rod was not in equilibrium. The explanations given did not always describe the reasons in detail.

(c)

(i) The majority of candidates did not take moments about one point. Candidates should be encouraged to practise questions where there are two unknown forces to be determined.

(ii) A number of candidates were able to gain credit by realising that the resultant force in the vertical direction was zero.

Question 3

(a) Most answers were correct. Candidates should be encouraged to give some working rather than merely writing down an answer.

(b)

(i) A significant number of candidates used an appropriate equation of motion and calculated the height correctly. Candidates should be encouraged to practice questions where the motions in a horizontal direction and vertical direction are treated separately.

(ii) The majority of answers were correct.

(iii) Many candidates did not realise that the time to return to the ground was the same as in **(ii)**, the time for the upward journey.

(c)

(i) The majority of candidates were unable to determine the initial momentum of the ball although the correct value for the horizontal component had been determined in **(a)(i)**. There were very few correct answers for the change in momentum.

(ii) This was generally well answered. Some candidates showed some confusion with conservation of energy, conservation of kinetic energy or conservation of momentum

Question 4

(a) The majority of candidates were unable to explain the difference between the two types of potential energy. It was expected that candidates should know that the key elements for the different potential energies were mass and charge.

(b) The derivations often lacked any explanation. Candidates should be encouraged to give solutions with an explanation of the symbols used and a statement between each step.

(c)

(i) There were a number of good solutions. A significant number of candidates found difficulty with the calculation involving a percentage.

(ii) Very few candidates obtained the correct answer. Again the efficiency calculation caused difficulty for the majority of candidates. Candidates would benefit from greater emphasis being placed on the application of basic principles to everyday situations.

Question 5

(a) Many candidates were not able to give an acceptable definition.

(b) Candidates generally gained at least partial credit for giving the defining equation for resistivity or its units.

(c)

(i) A significant number of candidates obtained the correct answer.

(ii) The majority of candidates were unable to interpret the series circuit and obtain the correct distribution of the potential difference across the two resistances.

(iii) Well prepared candidates calculated the correct answer.

(d)

(i) There were a number of correct answers. Application of a formula caused problems for some candidates.

(ii) Very few candidates were able to give the correct answer. Candidates did not appear to realise the effect on the circuit of adding a resistance with a very large value.

Question 6

(a) Well prepared candidates gave the correct definition. A significant number of candidates were unable to give the required definition.

(b)

(i) There were very few answers given with the required precision. A common error was to include a vague reference to a limit rather than the point beyond which the object does not return to its original length. Many candidates also omitted the condition of 'when the force is removed'. A significant minority also confused the elastic limit with the limit of proportionality.

(ii) A significant number of candidates were able to determine the correct value. There were powers of ten errors and misreading of the scales by the weaker candidates.

(iii) A number of candidates were able to obtain the correct value. A significant number of candidates used an inappropriate equation for the work done extending a spring.

(c) This part tested the understanding of the term 'spring constant'. Very few candidates were able to demonstrate a good understanding and hence correct answers were seldom seen. Candidates would benefit from further experience of solving problems involving spring constants.

Question 7

(a) The required explanation of an isotope was not well known by a large number of candidates. Candidates must refer to nuclei in their explanation of isotopes.

(b)

(i) Very few candidates were able to give the required quantity conserved in a nuclear reaction.

(ii) Well prepared candidates completed the analysis and gained full credit. It was clear that many candidates had not had sufficient practice with these types of reactions.

(c) A common error was to not to include the neutron absorbed by the uranium nucleus.

PHYSICS

Paper 9702/22

AS Structured Questions

Key Messages

- Many candidates would benefit from taking a moment to consider the numerical answers that they have obtained, especially as regards powers of ten. A quick check on whether an answer is 'reasonable' would allow candidates to detect errors in their working.
- Candidates should be encouraged not to 'round off' answers at intermediate stages of a calculation, as this can lead to inaccurate and inappropriate final answers.
- Candidates should be advised to use the data given on page 2 of the question paper. In particular, the use of the approximation $g = 10\,\text{m}\,\text{s}^{-2}$ should be discouraged.
- The application of knowledge of basic concepts to unfamiliar situations is often found to be difficult. Candidates who have difficulty would improve their performance if they spent time discussing and practising the application of basic concepts to new situations.
- Most candidates could improve their performance by learning the precise details of definitions and laws required by the syllabus. The wording of answers should relate to the question asked and a certain amount of precision is required at this level. A vague statement of the terms involved is generally not sufficient.

General Comments

There were few candidates who did not complete their answers to questions. There was no evidence amongst adequately prepared candidates of a shortage of time.

Candidates appeared to find **Questions 3**, **5** and **7** to be the most difficult. Responses did vary considerably between Centres.

Candidates should be encouraged to read carefully through any question before making any attempt with an answer. Generally the mark allocation indicates the required length and complexity of any answer.

Comments on Specific Questions

Question 1

(a) The majority of candidates were able to take readings to the required precision from the graph and obtain the expected value for the average velocity. One common error was to use the start and peak points of 0 and 45 seconds instead of those stated in the question. Only the very weakest candidates did not know the correct formula, misread the scales or attempted to calculate the area under the graph.

(b) Many candidates were unable to draw the required velocity–time graph using the changes to the gradient of the displacement–time graph. A significant number of these candidates only gained partial credit for starting with a zero velocity. Some candidates did make a good attempt at sketching the correct shape of the graph, but others did not accurately link the changes in the gradient of the displacement–time graph to the changes in the velocity. A very limited number of candidates realised that the velocity for the second half of the journey had negative values.

Question 2

(a)

(i) There were very many candidates that were unable to recall the definition required by the syllabus. Candidates that defined force as a push or pull or the product of mass and acceleration were not awarded credit. Candidates should be reminded that definitions and laws must be recalled with precision to gain credit.

(ii) Candidates should be advised that their must refer to the distance <u>moved in the direction of the force</u> to obtain full credit when defining work done.

(b)

(i) The majority of answers were correct.

(ii) The derivation is a requirement on the syllabus. Very few candidates were able to present a clear and precise derivation. Candidates should be encouraged to give an explanation of the sequence of steps required to link the work done with the change in kinetic energy.

(c)

(i) A large majority of candidates were able to obtain the correct value for the acceleration. A significant number of candidates went on to obtain the correct distance. The most common approach was to calculate the acceleration and then substitute this into an appropriate equation of motion. Only a small minority of candidates equated the work done to the change in kinetic energy.

(ii) There were very few correct explanations. The majority of candidates were unable to compare the change in kinetic energy in the two cases where the change in speed was the same.

Question 3

This question clearly indicated the need for candidates to read the question carefully. The answers given by many candidates showed the lack of knowledge and understanding of the precise definition of terms. There was also confusion between ductile and brittle materials and the elastic and proportional properties of these materials. Candidates who did not use a ruler to draw the graphs were often not awarded credit as the lines drawn were deemed not to be straight.

(a)

(i) The majority of candidates gave the correct answer.

(ii) Some candidates did not give a sufficiently precise definition. The definition required that strain is the extension divided by the <u>original</u> length.

A minority of candidates gave the definitions the wrong way round.

(b) There were very few answers given with the required precision. A common error was to include a vague reference to a limit rather than the point beyond which the object does not return to its original length. Many candidates also omitted the condition of ‘when the force is removed’. A significant minority also confused the elastic limit with the limit of proportionality.

(c) Many candidates did not give the accepted definition. Candidates did not refer to the <u>original</u> cross-sectional area or the maximum stress before it breaks. A large number of candidates referred to force rather than stress.

(d)

(i) The majority of graphs for the ductile material started correctly with a straight line through the origin but the plastic region was generally less well drawn with only a minority showing a large plastic region.

(ii) The majority of graphs for the brittle material were correct, but many were spoilt by a significant hook being drawn at the end.

(e)

(i) There were very few correct answers. Many candidates did not explain the features of the graphs that showed the characteristics of the ductile and brittle materials. The answers often described characteristics that could not be explained from the features of the graphs. Candidates need to be reminded to read the question carefully.

(ii) A significant number of answers were too vague to be worthy of any credit. In **1.** some answers implied that the material would continue extending when the force was removed. In **2.** some answers implied that there would be no change when the force was removed. The question needed to be read carefully.

A significant minority of candidates gave their answers in **(d)** and **(e)** the wrong way round.

Question 4

(a) There were many candidates who omitted ‘positive’ from their definition. This lack of precision meant that these candidates could not be awarded credit. A significant minority gave the potential gradient and this is not acceptable as the definition.

(b)

(i) The majority of candidates gained at least partial credit. Candidates should ensure they are more methodical in drawing straight lines that are equally spaced. A significant number of candidates did not use a ruler and hence the lines drawn were often deemed not straight. A significant minority did not draw anything on the diagram or drew lines between the circuit lines rather than between the metal plates.

(ii) The majority of candidates obtained the correct answer.

(iii) A significant number of candidates obtained the correct value for the magnitude of the charge. Only a small minority then gave the correct sign for the charge. The weaker candidates were able to gain partial credit for the expression of the electric force but were unable to equate the forces acting to keep the charge stationary.

(iv) The majority of candidates correctly stated that the charge would move upwards. The quality of the explanations was variable. Many candidates did not appear to have read the question carefully and the explanation for the subsequent motion of the charge often ignored that the charge had been stationary in **(iii)**. Very few candidates compared the weight of the drop with the new increased electric force.

Question 5

Candidates found this question particularly difficult.

(a)

(i) This was generally well answered.

(ii) There were very few correct answers. Many of the responses did not appreciate that the current in BJ was different from that in JF or that the resistance of JF was half that of BF.

(iii) A significant number of candidates correctly gave the e.m.f. of the two cells in opposite directions but very few went on to gain further credit by obtaining a completely correct relation.

(b) Many explanations referred to the resistance or potential difference of the wire or circuit changing rather than the resistance or potential difference between B and J. Candidates need to be more precise in their explanations in order to gain credit. Specific references to particular parts of the circuit were required.

Question 6

(a) A significant number of candidates gave the correct response. Less precise statements again meant that the weaker candidates were not generally awarded credit. There was often no explicit statement that the waves overlap. Some candidates made reference to amplitude rather than displacement, or omitted the phrase 'the sum of the displacements of the individual waves'.

(b) More able candidates generally gained at least partial credit here. The explanations often did not include the conditions for a stationary wave to form. The main conditions omitted were the same speed and frequency. The particular waves in this example that were overlapping were not always described clearly.

(c)

(i) The majority of candidates were able to read the oscilloscope trace correctly for one oscillation but many did not convert this to a correct time period or frequency. Errors with powers of ten were not uncommon amongst the weaker candidates.

(ii) **1.** There were a number of good responses with a correct reference to nodes and antinodes. A large number of candidates did not answer the question with reference to stationary waves and tried to relate the differences in amplitude to constructive and destructive interference.

2. Many candidates used an incorrect wavelength and only gained credit for the correct equation.

Question 7

(a) The majority of candidates did not answer the question, suggesting they had not read the question sufficiently carefully. The question asked for experimental observations, but most candidates instead gave explanations of the terms.

(b) The majority of candidates did not know the values required or did not give them in sufficient detail. Common errors included giving the charges as + and – instead of $+2e$ and $–e$, or giving speeds greater than c for the α-particle and γ-radiation.

(c) A number of candidates were able to gain at least partial credit. A significant number of candidates considered the loss of energy to be due to either the α-particle becoming ionised or it decaying.

PHYSICS

Paper 9702/23
AS Structured Questions

Key Messages

- Many candidates would benefit from taking a moment to consider the numerical answers that they have obtained, especially as regards powers of ten. A quick check on whether an answer is 'reasonable' would allow candidates to detect errors in their working.
- Candidates should be encouraged not to 'round off' answers at intermediate stages of a calculation, as this can lead to inaccurate and inappropriate final answers.
- Candidates should be advised to use the data given on page 2 of the question paper. In particular, the use of the approximation $g = 10\,\mathrm{m\,s^{-2}}$ should be discouraged.
- The application of knowledge of basic concepts to unfamiliar situations is often found to be difficult. Candidates who have difficulty would improve their performance if they spent time discussing and practising the application of basic concepts to new situations.
- Most candidates could improve their performance by learning the precise details of definitions and laws required by the syllabus. The wording of answers should relate to the question asked and a certain amount of precision is required at this level. A vague statement of the terms involved is generally not sufficient.

General Comments

There were few candidates who did not complete their answers to the questions. There was no evidence amongst adequately prepared candidates of a shortage of time.

Candidates should be encouraged to read carefully through any question before attempting to answer it. They should pay attention to the indicated mark allocation. Generally, the mark allocation indicates the required length and complexity of any answer. They should be advised not to commence any answer by writing out large portions of the question. This is very wasteful of valuable time.

Comments on Specific Questions

Question 1

(a) This was generally well answered with references to both magnitude and direction.

(b) The most common misconceptions were that power was included as a vector and that weight was thought to be a scalar quantity.

(c) Most answers were correct. Candidates should be encouraged to give some explanation, rather than merely writing down the answer.

(d) The great majority of answers were obtained by calculation, rather than by drawing. There were many sound answers where explanation was good. Most candidates did show clearly resolution in the horizontal and in the vertical directions. This did, subsequently, involve some mathematics when deriving the answers. A minority realised that the strings are normal to one another and thus, by resolving along each string, mathematical manipulation was reduced to a minimum.

Question 2

(a) For stage 1, most answers did include a reference to constant velocity. However, for stage 2, although it was realised that the velocity is decreasing, the fact that the decrease is constant was not included.

(b)

(i) With few exceptions, the area between the line and the *t*-axis was calculated. There were relatively few errors when reading values for *t* from the graph.

(ii) In most answers, it was realised that the acceleration should be calculated and then substituted into the formula $F = ma$. It was not uncommon to find that, when calculating the acceleration, an incorrect value for the elapsed time was substituted.

(c)

(i) Most statements were adequate. It was expected that candidates would realise that the distance is reduced because the speed is less.

(ii) In general, the answer given was that the distance would be halved. Most candidates did not realise that, not only is the initial speed halved but also, the time to come to a halt is reduced. Very few candidates attempted to answer the question by reference to an equation of motion. Most attempted a verbal argument rather than invoke the equation $v^2 = u^2 + 2as$.

Question 3

(a)

(i) Generally, definitions were satisfactory. Candidates should be advised that power involves a transfer of energy and, therefore, defining power as being 'energy/time' is not sufficient.

(ii) With few exceptions, definitions were satisfactory.

(b)

(i) **1.** Candidates should be advised to show all working clearly, especially where they are asked to derive a given quantity. In a significant number of answers, it was not possible to decide whether the factor of 0.0010 had been written in the numerator or in the denominator of the stated expression.

2. The use of $g = 10\,\mathrm{m\,s^{-2}}$ should be discouraged. The data supplied in the question paper should be employed. A significant minority gave an answer of $17.2\ \mathrm{m\,s^{-2}}$ because the candidate had not made allowance for the weight of the load.

(ii) **1.** Although there were many correct answers, it was not uncommon to find that the tension was assumed to be that when the weight was accelerating.

2. The calculation of the gain in potential energy presented very few problems.

(iii) Most candidates did use the expression $P = Fv$. Some then confused this power with the input power. A significant minority calculated the kinetic energy of the mass and then used this in an expression for power. This kinetic energy did not represent any change in energy.

Question 4

(a) Most statements were satisfactory with reference being made to 'other forms of energy'. Candidates should be advised not to make specific reference to 'chemical energy' when referring to e.m.f. or to 'thermal energy' for potential difference.

(b)

(i) Answers here were generally satisfactory although there was some confusion with Kirchhoff's first law.

(ii) In many answers, the sum of the e.m.f.s was calculated, rather than the difference.

(iii) Some candidates did not answer this part of the question, perhaps because they missed it unintentionally. Candidates should be advised to read the question paper carefully.

(iv) In general, **part 1** was answered correctly when allowance was made for the candidate's value of current. Many answers in **parts 2** and **3** were incorrect. In most of these cases, the e.m.f. was not included and each response involved solely the product of current and an internal resistance.

Question 5

(a) Answers were, in general, satisfactory although a significant number did not refer to direction of energy transfer. There were numerous references to 'direction of the wave'.

(b) Candidates should appreciate that the vibrations are in one direction only. Reference to 'vibrations in only one plane', without careful definition of the plane, could apply to any transverse wave.

(c)

(i) There were very few problems when determining the amplitude. Only a minority could give a correct numerical value for the phase difference, and the unit was missing in many instances.

(ii) Although the majority of answers were correct, there was significant confusion as to the use of the expression $I \propto A^2$.

Question 6

(a) A significant number of answers did not include any explanation. Consequently, full credit could not be given.

(b)

(i) This was generally well answered by reference to opposite charges and deflection to named plates.

(ii) There were many correct responses. However, a minority made reference to mass in *u* and then became confused when dealing with the mass of the β-particle.

(iii) In most answers, it was realised that, in general, a β-particle has a higher speed. The effect of this higher speed, when isolated from other factors, was understood by only a minority of candidates.

(c) Very few candidates arrived at the correct answer. In the majority of cases, only mass or only charge was considered, even where the expression $a = Eq/m$ was quoted.

PHYSICS

Paper 9702/31
Advanced Practical Skills 1

Key Messages

- The skills tested in **Question 1** are listed in detail in the syllabus. Candidates need experience of using the relevant measuring equipment, and must be able to present results and calculations clearly to score high marks.

- Candidates should aim to make graphical work user friendly and choose appropriate scales to make finding points and interpreting gradient read-offs easy. Candidates should be encouraged not to make the plots occupy the whole grid by using awkward scales. As long as the plots occupy half of the grid, it is possible for sensible scales to be used at all times.

- Candidates should be encouraged to draw lines of best fit that take into account all of the plotted points. If the candidate believes a point to be anomalous, and has ignored it when drawing the line of best fit, then the anomalous point should be clearly indicated on the graph. If no anomalous point is indicated, the Examiners will judge the line on all of the plotted points.

- **Question 2** tests some of the same skills but it also requires discussion about the design of the experiment. Marks are available for explaining why some measurements have large uncertainties and for suggesting how these could be improved by using different measuring equipment or by changed procedures. There are not often many 'standard' answers – careful consideration of the individual experiment is needed. Credit is not normally given for describing common good practice (such as checking for zero errors or repeating readings) because candidates should already be using these techniques as they carry out the experiment.

General Comments

The general standard of the work done by the candidates was good, similar to last year.

Centres should note that any deviation from the requested equipment should be written down in the Supervisor's Report, and Cambridge should be notified so that the Examiners can take this into consideration during the marking period. Any help given to candidates should be noted on the Supervisor's Report. 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. Most candidates were confident in the generation and handling of data and their responses to the critical evaluation of their own experiment skills has again improved. However, there are still a number of Centres in which candidates should be reminded that, in the evaluation section, they should state the actual problems they encountered in carrying out the second experiment and then suggest possible and feasible solutions.

There were no common misinterpretations of the rubric.

Comments on Specific Questions

Question 1

In this question, candidates were required to investigate the equilibrium position of a metre rule with a mass attached to one end.

Successful collection of data

(a)

(ii) Most candidates measured the distance *k* within range.

(b)

(iii) Many candidates were able to measure the lengths *d* and *D*. Some candidates omitted units.

(c) Most candidates were able to set up the apparatus and then tabulate six sets of values for 1/*D* and (*D*–*d*)/*D*.

Range and distribution of values

(c) Many candidates did not extend a range of readings of *d* over at least 40 cm. A 1 m rule was provided and *d* can feasibly extend over half this length.

Presentation of data and observations

Table

(c) Many candidates were able to include correct units with the column headings including 1/*D* (cm^{-1}). Some candidates wrote 1/*D* (cm) or 1/*D*(cm). This should be discouraged as the unit stated should be that of the whole column heading, not a part of it. Some candidates omitted a separating mark between the column heading and the unit. Many candidates correctly stated the raw values of *d* and *D* to the nearest mm as the rule can measure to the nearest mm, whilst other candidates incorrectly gave *d* or *D* to the nearest cm only. Candidates were more likely to make errors if their values of *d* or *D* were stated in m (and not cm).

Many candidates were able to state the significant figures in the calculated quantity 1/*D* to the same as, or one more than, the number used for the corresponding raw value of *D.* Candidates should be encouraged not to round down the number of significant figures used as this will affect the quality of their data. The number of significant figures in the calculated quantity does not necessarily have to be the same down the column but relate back to the raw data, and so should be checked row by row. Most candidates correctly calculated (*D*–*d*)/*D.*

Graph

(d) Candidates were able to plot a graph of (*D*–*d*)/*D* against 1/*D* with many candidates using sensible scales leading to easy plotting and accurate read offs. However, there were candidates who drew awkward scales (1:7 or 1:3), scales containing gaps, or scales with the origin included (so the plots did not extend over half of the graph grid). Some weak candidates left 1/*D* in a fraction form and tried to produce a graph scale on that basis. Some candidates plotted 'points' that were greater than half a small square in diameter. Candidates are advised to use a sharp pencil. Several candidates plotted points more than half a small square out from the correct position. Candidates are encouraged to check their plotting.

Many candidates were able to draw an acceptable line of best fit from all of their points plotted. Some lines could be rotated to give a better fit. Some lines were clearly drawn with two short lengths of ruler leading to a kink at the join, whilst other lines were drawn by joining up the first and last points. Candidates are advised to use a sharp pencil and a 30 cm clear plastic ruler. Some candidates plotted a point off the grid area.

Analysis, conclusions and evaluation

Interpretation of graph

(d)

(iii) Most candidates used a suitably large triangle to calculate the gradient. Some candidates need to check that the read-offs used are within half a small square of the best fit line drawn, show their substitution clearly into $\Delta y/\Delta x$ (not $\Delta x/\Delta y$) and check that their triangle is at least half the length of the line drawn in order to gain credit.

Some candidates read off the *y*-intercept at $1/D = 0$ successfully gaining credit. However a small number of candidates did not check that the *x*-axis started at $1/D = 0$ before reading off the *y*-intercept (false origin) and so did not gain credit. Many candidates substituted into $y = mx + c$ successfully to determine the *y*-intercept. When using this method the point used must lie on the line of best fit and not just be taken from the table.

Drawing conclusions

(e) Many candidates were able to give the values of *A* and *B* with consistent units and using the correct method with gradient and intercept values taken from **(d)(iii)**. Some candidates omitted units, used a substitution method, or gave an answer out of range (by forgetting to convert cm into m) and so did not gain full credit.

Question 2

In this question, candidates were required to investigate how the motion of a thin card shape depends on its size.

Successful collection of data

(a) Some candidates correctly measured thickness *t* to a precision of 0.01 mm. Some candidates measured *t* to the nearest mm suggesting that they had not used the micrometer screw gauge. Other candidates incorrectly measured to a precision of 0.1 mm.

(b)

(i) Many candidates were able to measure *L* in range to the nearest mm. A few candidates omitted the units. A few candidates measured to the nearest cm.

(e) Many candidates correctly recorded *T* to be less than 1.5 s using repeat readings. A few candidates recorded greater times or showed no working to indicate that repeats had been taken.

(f),**(g)** Most of the candidates were able to obtain second readings of *L* and *T* for the shorter shape.

Quality

(g) Most candidates found that the time *T* taken for one complete swing was larger for the longer shape.

Presentation of data and observations

Display of calculation and reasoning

(c)

(ii) Some candidates successfully calculated the value of the volume *V* of the shape. Many candidates mixed up their units of m and cm in the calculation so that the final unit given was inconsistent.

(h)

(i) Many candidates were able to calculate *k* for the two sets of data. A few candidates forgot to square *T* or incorrectly rearranged the equation to find *k*.

(ii) Some candidates correctly linked the significant figures in *k* to their raw data for time and *L*. Some candidates related their significant figures to T^2 instead of back to the raw time. Some candidates related to the raw data without saying how many significant figures they would actually use.

Analysis, conclusions and evaluation

(h)

(iii) Some candidates correctly compared their values of *k* using a percentage difference, and then linked this to a judgement of whether or not their results supported the given relationship by comparing the percentage difference in *k* with some sort of experimental criterion. The criterion can come from the percentage uncertainty in **(b)(ii)** or with an estimated or calculated experimental uncertainty. Some candidates worked out the percentage difference correctly but omitted to compare it with any criterion. A few candidates did not carry out any calculations.

Estimating uncertainties in *L*

(b)

(ii) Many candidates stated the correct ratio idea (×100) for working out the percentage uncertainty, gaining credit. Many candidates gave the uncertainty in *L* correctly as 1 or 2 mm.

Evaluation

(i) Many candidates gained credit in this section and the quality of written answers is improving. Candidates should be encouraged to look at the experiment and state what problems they had and offer some credible solutions. Candidates should approach this by asking themselves 'why is this measurement difficult?' The key to this section is for candidates to identify real problems associated with setting up this experiment and obtaining readings (e.g. card does not swing freely, oscillations die out quickly, or difficult to judge the beginning/end of an oscillation). Candidates can improve their written answers by suggesting a practical method to use for each problem which would either improve the technique or give more reliable data (e.g. make the hole bigger so that the card can swing more freely or use a fiducial marker). In doing this, candidates look at how each solution helps this particular experiment. Candidates most often gained credit for stating that the oscillations were not always in the same plane, the card did not swing freely, and there were too few readings to draw a conclusion. Candidates did not gain credit for stating the use of light gates or by suggesting the use of an assistant. Candidates are encouraged to avoid changing the experiment to a different one (e.g. test metal shapes instead of thin card shapes). A comprehensive list of problems and solutions can be found in the mark scheme.

PHYSICS

Paper 9702/33

Advanced Practical Skills 1

Key Messages

- The skills tested in **Question 1** are listed in detail in the syllabus. Candidates need experience of using the relevant measuring equipment, and must be able to present results and calculations clearly to score high marks.

- Candidates should aim to make graphical work user friendly and choose appropriate scales to make finding points and interpreting gradient read-offs easy. Candidates should be encouraged not to make the plots occupy the whole grid by using awkward scales. As long as the plots occupy half of the grid, it is possible for sensible scales to be used at all times.

- Candidates should be encouraged to draw lines of best fit that take into account all of the plotted points. If the candidate believes a point to be anomalous, and has ignored it when drawing the line of best fit, then the anomalous point should be clearly indicated on the graph. If no anomalous point is indicated, the Examiners will judge the line on all of the plotted points.

- **Question 2** tests some of the same skills but it also requires discussion about the design of the experiment. Marks are available for explaining why some measurements have large uncertainties and for suggesting how these could be improved by using different measuring equipment or by changed procedures. There are not often many ‘standard’ answers – careful consideration of the individual experiment is needed. Credit is not normally given for describing common good practice (such as checking for zero errors or repeating readings) because candidates should already be using these techniques as they carry out the experiment.

General Comments

The general standard of the work done by the candidates was good, similar to last year.

Centres should note that any deviation from the requested equipment should be written down in the Supervisor’s Report, and Cambridge should be notified so that the Examiners can take this into consideration during the marking period. Any help given to candidates should be noted on the Supervisor’s Report. 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. Most candidates were confident in the generation and handling of data and their responses to the critical evaluation of their own experiment skills has again improved. However, there are still a number of Centres in which candidates should be reminded that, in the evaluation section, they should state the actual problems they encountered in carrying out the second experiment and then suggest possible and feasible solutions.

There were no common misinterpretations of the rubric.

Comments on Specific Questions

Question 1

In this question, candidates were required to determine the resistivity of a metal wire.

Successful collection of data

(a)

(i) Some candidates measured the diameter *d* to the nearest mm instead of making use of the micrometer screw gauge provided to give readings to a precision of 0.01 mm.

(b)

(iii) Many candidates were able to measure the length of the wire between the two crocodile clips and the voltage across the wire. Some candidates omitted units, did not read the length to the nearest mm, did not set the first length so that the second crocodile clip was approximately half way along the wire, or read 400 mV as 400 V.

(c) Most candidates were able to set up the apparatus and tabulate six sets of values for l and V. Some candidates had minimal voltage variation suggesting that the circuit was incorrectly set up with the voltmeter across the supply whilst other candidates stated an incorrect trend owing to reading off the wrong scale or the wrong end of the metre rule.

Range and distribution of values

(c) Many candidates did not extend a range of readings of l over at least 50 cm. Given that a 1 m length of wire on the rule was provided, the range in l is expected to extend over most of this length. There was a tendency for candidates to start at the 50 cm mark and go up in tens to 100 cm when a wider range could have been used.

Presentation of data and observations

Table

(c) Many candidates were able to include correct units with the column headings including $1/l$ (cm^{-1}) and $1/V$ (V^{-1}). Some candidates wrote $1/l$ (cm) or $1/l$(cm). This should be discouraged as the unit stated should be that of the whole column heading, not a part of it. Sometimes the separating mark between the column heading and the unit was omitted. Many candidates correctly stated the raw values of l to the nearest mm as the rule can measure to the nearest mm, whilst other candidates incorrectly gave l to the nearest cm only. Candidates were more likely to make errors if their values of l were stated in m (and not cm).

Many candidates were able to state the significant figures in the calculated quantity $1/V$ to the same as, or one more than, the number used for the corresponding raw value of V. Candidates should be encouraged not to round down the number of significant figures used as this will affect the quality of their data. The number of significant figures in the calculated quantity does not necessarily have to be the same down the column but should relate back to the raw data, and so should be checked row by row. The majority of candidates were able to calculate $1/V$ correctly.

Graph

(d) Candidates were able to plot a graph of $1/V$ against $1/l$ with many candidates using sensible scales leading to easy plotting and accurate read offs. However, there were candidates who drew awkward scales (1:7 or 1:3), scales with gaps, or scales with the origin included (so the plots did not extend over half of the graph grid). Some weak candidates left $1/l$ in a fraction form and tried to produce a graph scale on that basis. Some candidates plotted ‘points’ that were greater than half a small square in diameter. Candidates are advised to use a sharp pencil. Several candidates plotted points more than half a small square out from the correct position. Candidates are encouraged to check their plotting.

Many candidates were able to draw an acceptable line of best fit from all of their points plotted. Some lines could be rotated to give a better fit. Some lines were clearly drawn with two short lengths of ruler leading to a kink at the join, whilst other lines were drawn by joining up the first and last points. Candidates are advised to use a sharp pencil and a 30 cm clear plastic ruler. Some candidates plotted a point off the grid area.

Analysis, conclusions and evaluation

Interpretation of graph

(d)

(iii) Most candidates used a suitably large triangle to calculate the gradient. Some candidates need to check that the read-offs used are within half a small square of the best fit line drawn, show their substitution clearly into $\Delta y/\Delta x$ (not $\Delta x/\Delta y$) and check that their triangle is at least half the length of the line drawn in order to gain credit.

Some candidates read off the *y*-intercept at $1/V = 0$ successfully gaining credit. However a significant number of candidates did not check that the *x*-axis started at $1/V = 0$ before reading off the *y*-intercept (false origin) and so did not gain credit. Many candidates substituted into $y = mx + c$ successfully to determine the *y*-intercept. When using this method the point used must lie on the line of best fit and not just be taken from the table.

Drawing conclusions

(e) Many candidates were able to give the values of *M* and *N* with consistent units and using the correct method with gradient and intercept values taken from **(d)(iii)**. Some candidates omitted units, used a substitution method, or gave an answer out of range (by forgetting to convert cm into m or mV into V) and so did not gain full credit.

Question 2

In this question, candidates were required to investigate how the motion of a metre rule depends on the length of the string loops used to suspend it.

Successful collection of data

(a) Many candidates correctly measured width *w* to the nearest mm. Some candidates incorrectly measured *w* to a greater degree of precision. Some candidates recorded the thickness instead of the width.

(b) Many candidates were able to measure *l* to the nearest mm. A few candidates omitted the units. A few candidates halved the full length to get *l* without having tied a knot.

(d) Many candidates correctly recorded *T* to be less than 1.5 s using repeat readings. A few candidates recorded greater times or showed no working to indicate that repeats had been taken.

(e) Most of the candidates were able to obtain second readings of *l*, *d* and *T* for the shorter length of string.

Quality

(e) Most candidates found that the time taken for one complete swing *T* was larger for the longer length of loop.

Presentation of data and observations

Display of calculation and reasoning

(c)

(ii) Many candidates successfully calculated the value of *d*. A few candidates subtracted one width instead of two from *l* to get *d*.

(f)

(i) Many candidates were able to calculate *k* for the two sets of data. A few candidates forgot to square *T* or incorrectly rearranged the equation to find *k*.

(ii) Some candidates correctly linked the significant figures in *k* to their raw data for time and either *d* or *l*. Some candidates related their significant figures to T^2 instead of back to the raw time. Some candidates related to the raw data without saying how many significant figures they would actually use.

Analysis, conclusions and evaluation

(f)

(iii) Some candidates correctly compared their values of *k* using a percentage difference, and then linked this to a judgement of whether or not their results supported the given relationship by comparing the percentage difference in *k* with some sort of experimental criterion. The criterion can come from the percentage uncertainty in **(c)(iii)** or with an estimated or calculated experimental uncertainty. Some candidates worked out the percentage difference correctly but omitted to compare it with any criterion. A few candidates did not carry out any calculations.

Estimating uncertainties in *d*

(c)

(iii) Many candidates stated the correct ratio idea (×100) for working out the percentage uncertainty, gaining credit. Many candidates gave the uncertainty in *d* as just 1 mm without further consideration. Candidates are encouraged to consider a realistic uncertainty in the calculated distance (i.e. 3 – 15 mm) as this depends on both *l* and *w* measurements and does not take the thickness of the ruler into account.

Evaluation

(g) Many candidates gained at least partial credit in this section and the quality of written answers has again improved. Candidates are now more likely to look at the experiment and state what problems they had, and then offer some solutions. The key to this section is for candidates to identify real problems associated with setting up this experiment (e.g. loops not exactly the same size and so the ruler did not lie horizontally) and in obtaining the readings. Candidates should be encouraged to ask themselves ‘why is this measurement difficult?’ Candidates can improve their written answers by suggesting a practical method to use for each problem which would either improve the technique or give more reliable data. In doing this, candidates should look at how each solution helps this particular experiment. Candidates most often gained credit for stating that the ruler was not horizontal (however ‘not straight’ did not gain credit), the loops were of different sizes, the loops slid along the ruler and there were too few readings to draw a conclusion. Candidates did not gain credit for stating that the clamps were not at the same level (the candidate can change this during the experiment) or for suggesting the use of pre-made loops or having an assistant. Candidates are encouraged to avoid changing the experiment to a different one (e.g. test with rubber bands instead of string loops). A comprehensive list of problems and solutions can be found in the mark scheme.

PHYSICS

Paper 9702/34
Advanced Practical Skills 2

Key Messages

- The skills tested in **Question 1** are listed in detail in the syllabus. Candidates need experience of using the relevant measuring equipment, and must be able to present results and calculations clearly to score high marks.

- Candidates should aim to make graphical work user friendly and choose appropriate scales to make finding points and interpreting gradient read-offs easy. Candidates should be encouraged not to make the plots occupy the whole grid by using awkward scales. As long as the plots occupy half of the grid, it is possible for sensible scales to be used at all times.

- Candidates should be encouraged to draw lines of best fit that take into account all of the plotted points. If the candidate believes a point to be anomalous, and has ignored it when drawing the line of best fit, then the anomalous point should be clearly indicated on the graph. If no anomalous point is indicated, the Examiners will judge the line on all of the plotted points.

- **Question 2** tests some of the same skills but it also requires discussion about the design of the experiment. Marks are available for explaining why some measurements have large uncertainties and for suggesting how these could be improved by using different measuring equipment or by changed procedures. There are not often many 'standard' answers – careful consideration of the individual experiment is needed. Credit is not normally given for describing common good practice (such as checking for zero errors or repeating readings) because candidates should already be using these techniques as they carry out the experiment.

General Comments

There were few problems with providing the necessary apparatus for **Question 1**. Some of the polythene strips used in **Question 2** did not break at the load specified in the Confidential Instructions.

Centres should note that any deviation from the requested equipment should be written down in the Supervisor's Report, and Cambridge should be notified so that the Examiners can take this into consideration during the marking period. Any help given to candidates should be noted on the Supervisor's Report. Supervisors are reminded that under **no circumstances** should help be given with the recording of results, graphical work or analysis.

Candidates had time to complete both questions and, in most cases, the instructions were understood and followed carefully. There was variation between Centres, but most candidates had been prepared very effectively in the presentation of data in tables and graphs, leading to a generally good performance in **Question 1**. A number of candidates had difficulty using the micrometer screw gauge in **Question 2**, although the challenging discussion section at the end of the question was well answered.

Comments on Specific Questions

Question 1

In this question, candidates were required to investigate the behaviour of an electrical circuit.

Successful collection of data

(b) Nearly every candidate recorded a sensible value for the initial voltmeter reading. Some omitted the unit; all measured values should include a unit unless a unit is given on the answer line.

(c) Nearly all candidates recorded results for six different resistors. For this experiment *V* increases as *R* increases, with negative values of *V* where *R* is less than 1 kΩ. Some candidates ignored negative signs, and some had connected their circuit incorrectly. A request for help could have put this right and would only have incurred a small penalty.

Range and distribution of values

(c) Resistances from 0.22 to 6.8 kΩ were available, and the strongest candidates used a suitably large part of this range by including values close to the maximum and the minimum.

Presentation of data and observations

Table

(c) Tables were generally neat and clear, with very good consistency of values (only a few candidates recorded zero volts as 0 V rather than 0.00 V). The choice of number of significant figures in the calculated values was generally good.

Graph

(d)

(i) Graphs were generally of a high standard. Most scales were sensible and chosen to use at least half the length of each axis, but candidates from some Centres used very awkward scales and a few used different scales for the negative portion of the *y*-axis.

Plotting was usually clear and accurate and most candidates avoided 'blobs' by using a sharp pencil.

The quality of results (as indicated by scatter on the graph) was very good if the circuit was correct.

(ii) Many candidates chose a suitable best fit line.

Analysis, conclusions and evaluation

Interpretation of graph

(d)

(iii) Nearly every candidate knew how to find the gradient of their graph, and the only errors were in using too small a triangle or mis-reading coordinates. The *y*-intercept could be read directly from the graph if there was no false origin, but most candidates chose to calculate it, usually successfully. Centres had prepared candidates well in the clear presentation of their working.

Drawing conclusions

(e) This section was well answered. Most candidates compared their graph with the equation relating *V* and *R* and then correctly equated their gradient to *a* and their intercept to –*b*. Many gained further credit if their value of *b* was close to the theoretical value of half the supply p.d.

Question 2

In this question, candidates were required to investigate the force needed to break a polythene strip.

Successful collection of data

(a) Many candidates struggled to record the micrometer reading correctly when measuring the polythene thickness. Others found values outside the range specified in the Confidential Instructions; allowance was made for this if supported by evidence provided by the Centre in its Supervisor's Report.

(b)

(i) Most candidates recorded a sensible value for *w*, but some made errors when converting their reading to the millimetres specified on the answer line (comparison with an estimate would have made this obvious). Many gained additional credit for recording repeat values using the other strips.

(d),**(e)** The recording and averaging of the breaking forces for each set of four strips was usually well done. A few Centres had provided strips which did not break at the specified force ($< 10\,N$). Affected candidates may well have been unsettled by the discrepancy but could still go on to achieve nearly all the available credit provided they carefully recorded what they saw (for example: 'all values of F were $> 10\,N$, so the average was $> 10\,N$'). It is important that Centres take care to provide the specified apparatus to avoid such problems.

Estimating uncertainties

(b)

(ii) Most candidates knew the method for calculating percentage uncertainty. Many either chose an unsuitable value for Δw such as 0.1 mm or even 0.01 mm (*w* could be measured to the nearest millimetre with the rule provided), or mixed their units in the calculation.

Presentation of data and observations

Display of calculation and reasoning

(c) Nearly every candidate correctly calculated the cross-sectional area.

(f)

(i) Calculation of the two values of *k* was well done by the majority of candidates.

Conclusions

(f)

(ii) Candidates from many Centres had been well prepared and answered this section well. Most candidates knew that they had to compare their two values for the 'constant' *k* to come to a conclusion and that they had to specify the tolerance used (e.g. 'within 20 %' or 'within the experimental uncertainty in **(b)(ii)**'). Stating that 'the difference is too large' is too vague and is not credited.

Evaluation

(g) This section was often well answered, with strong candidates receiving most of the credit available for clear descriptions of difficulties and improvements. As in previous years the weaker answers tended to lack detail or relevance to the actual investigation undertaken (problems such as air conditioning fans and parallax were not significant in this experiment) and 'improvements' that could have been carried out with the apparatus already provided were not credited.

Three measurements were involved in this experiment: thickness *t*, width *w* and force *F*. Each of these could have been considered and problems identified:

t – this measurement had a large percentage uncertainty – how could it be reduced?

w – it was hard to see the end of the cuts clearly if the polythene was the same colour as the background – how could they be made clearer, given that the polythene colour could not be changed (this would be changing the object of the experiment)?

F – there was a problem in judging the maximum value on the newton meter - how could this be improved?

(i) The most common difficulties to be identified were 'two values of *k* are not enough to evaluate the relationship', 'it was difficult to judge the maximum force reading', 'it was hard to see the ends of the cuts' and 'the adhesive tape detaches from the bench'.

(ii) Many candidates' ideas for improvements included sufficient practical detail (such as 'use video recording with slow motion playback' or 'fix strip to bench using a clamp').

The published mark scheme shows the other responses that were accepted.

PHYSICS

Paper 9702/35

Advanced Practical Skills 1

Key Messages

- The skills tested in **Question 1** are listed in detail in the syllabus. Candidates need experience of using the relevant measuring equipment, and must be able to present results and calculations clearly to score high marks.

- Candidates should aim to make graphical work user friendly and choose appropriate scales to make finding points and interpreting gradient read-offs easy. Candidates should be encouraged not to make the plots occupy the whole grid by using awkward scales. As long as the plots occupy half of the grid, it is possible for sensible scales to be used at all times.

- Candidates should be encouraged to draw lines of best fit that take into account all of the plotted points. If the candidate believes a point to be anomalous, and has ignored it when drawing the line of best fit, then the anomalous point should be clearly indicated on the graph. If no anomalous point is indicated, the Examiners will judge the line on all of the plotted points.

- **Question 2** tests some of the same skills but it also requires discussion about the design of the experiment. Marks are available for explaining why some measurements have large uncertainties and for suggesting how these could be improved by using different measuring equipment or by changed procedures. There are not often many 'standard' answers – careful consideration of the individual experiment is needed. Credit is not normally given for describing common good practice (such as checking for zero errors or repeating readings) because candidates should already be using these techniques as they carry out the experiment.

General Comments

The general standard of work done by the candidates was good, similar to last year.

Centres should note that any deviation from the requested equipment should be written down in the Supervisor's Report, and Cambridge should be notified so that the Examiners can take this into consideration during the marking period. Any help given to candidates should be noted on the Supervisor's Report. 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. Most candidates were confident in the generation and handling of data and their responses to the critical evaluation of their own experiment skills has again improved. However, there are still a number of Centres in which the candidates should be reminded that, in the evaluation section, they should state the actual problems they encountered in carrying out the second experiment and then suggested possible and feasible solutions.

There were no common misinterpretations of the rubric.

Comments on Specific Questions

Question 1

In this question, candidates were required to investigate how the depth to which a beaker is submerged in water depends on the mass added to the beaker.

Successful collection of data

(a) Some candidates stated the height *h* to the nearest 0.1 mm instead of a precision of 1 mm that would have been appropriate from a simple measurement using the rule.

(b) Most candidates were able to measure the depth *d* with a smaller value than the height *h*. Some candidates omitted the unit.

(d) Nearly all candidates were able to set up the apparatus and tabulate six sets of values for *m* and *d*.

Range and distribution of values

(d) Many candidates did not extend a range of readings of *m* over at least 60 g. Given that a 50 g mass and five 10 g masses were provided, the range in *m* is expected to extend over most of the available 100 g range. There was a tendency for candidates to start at 50 g and go up in tens to 100 g when a wider range could have been used.

Presentation of data and observations

Table

(d) Many candidates were able to include correct units with the column headings including *m*/*d* ($g\,cm^{-1}$) and 1/*d* (cm^{-1}). Some candidates omitted one or more units or omitted a separating mark between the column heading and the unit. Many candidates correctly stated the raw values of *d* to the nearest mm as the rule can measure to the nearest mm, whilst other candidates incorrectly stated 0.5 mm or even 0.1 mm precision.

Many candidates were able to state the significant figures in the calculated quantity 1/*d* to the same as, or one more than, the number used for the corresponding raw value of *d.* Candidates should be encouraged not to round down the number of significant figures used as this will affect the quality of their data. The number of significant figures in the calculated quantity does not necessarily have to be the same down the column but should relate back to the raw data, and so should be checked row by row. The majority of candidates were able to calculate *m*/*d* correctly.

Graph

(e)

(i) Most candidates were able to plot a graph of *m*/*d* against 1/*d* with many candidates using sensible scales leading to easy plotting and read offs. However, there were candidates who drew awkward scales (1:7 or 1:3), drew scales containing gaps, or insisted on the origin being included (so the plots did not extend over half of the graph grid). Some weaker candidates left 1/*d* in a fraction form and tried to produce a graph scale on that basis. Many candidates plotted six points correctly. Some candidates plotted 'points' that were greater than half a small square in diameter. Candidates are advised to use a sharp pencil. Several candidates plotted points more than half a small square out from the correct position. Candidates are encouraged to check their plotting. Some candidates plotted a point off the grid area or omitted one of the points completely.

(ii) Many candidates were able to draw an acceptable line of best fit from all of the points plotted. Some lines could be rotated round to give a better fit. Some lines were clearly drawn with two short lengths of ruler leading to a kink at the join, whilst other lines were drawn by joining up the first and last points. Candidates are advised to use a sharp pencil and a 30 cm clear plastic ruler.

Analysis, conclusions and evaluation

Interpretation of graph

(e)

(iii) Most candidates used a suitably large triangle to calculate the gradient. Some candidates need to check that the read-offs used are within half a small square of the best fit line drawn, show their substitution clearly into $\Delta y/\Delta x$ (not $\Delta x/\Delta y$) and check that their triangle is at least half the length of the line drawn in order to gain credit.

Some candidates read off the y-intercept at $1/d = 0$ successfully gaining credit. However a significant number of candidates did not check that the x-axis started at $1/d = 0$ before reading off the y-intercept (false origin). Many candidates substituted into $y = mx + c$ successfully to determine the y-intercept. When using this method the point used must lie on the line of best fit and not just be taken from the table.

Drawing conclusions

(f) Many candidates were able to calculate the least value of m that would be needed to completely submerge the beaker using the correct method with gradient and intercept values taken from **(e)(iii)**. Candidates also needed to substitute the value of h from **(a)** for d. Some candidates used gradient = A, substituted an incorrect value for d, omitted the unit for m, or gave an answer out of range.

Question 2

In this question, candidates were required to investigate how the rate of heat energy transferred from a resistor depends on the voltage across it.

Successful collection of data

(a)

(ii) Most candidates correctly converted the volume in ml to mass, with consistent unit. Some candidates omitted the unit or were too far away from the expected value of 50 g.

(b)

(iii) Most candidates measured an appropriate voltage to at least 0.1 V precision. Some candidates omitted the unit.

(c) Many candidates measured the initial temperature successfully to the nearest °C. A similar proportion attempted to read the thermometer to higher precision and did not gain credit.

(d)

(ii) Most of the candidates were able to obtain a second value of the temperature after four minutes. Some candidates omitted the unit or recorded the unit as ° rather than °C.

(e) Nearly all candidates measured and recorded a second voltage larger than the first.

(f) Nearly all candidates measured and recorded a second pair of temperature readings.

Quality

(f) Nearly all candidates found that the temperature rise was larger for the larger voltage.

Presentation of data and observations

Display of calculation and reasoning

(d)

(iii) Nearly all candidates correctly calculated the temperature rise.

(g)

(i) Many candidates were able to calculate k for the two sets of data. A few candidates forgot to square V or incorrectly rearranged the equation to find k.

(ii) Very few candidates correctly linked the significant figures in k to their data for V and $(\theta_2 - \theta_1)$. Many candidates related their significant figures back to θ_2 and θ_1 without realising the number of significant figures would reduce when the subtraction is performed. Some candidates related their significant figures to V^2 instead of back to the raw V. Some candidates related their significant figures to the "raw data" without specifying the actual quantities involved.

Analysis, conclusions and evaluation

(g)

(iii) Some candidates correctly compared their values of *k* using a percentage difference, and then linked this to a judgement of whether or not their results supported the given relationship by comparing the percentage difference in *k* with some sort of experimental criterion. The criterion can come from the percentage uncertainty in **(a)(iii)** or with an estimated or calculated experimental uncertainty. Some candidates worked out the percentage difference correctly but omitted to compare it with any criterion. A few candidates did not carry out any calculations.

Estimating uncertainties in *m*

(a)

(iii) Many candidates used a realistic absolute uncertainty estimate of 1 g to 5 g and stated the correct ratio idea (×100) for working out the percentage uncertainty gaining credit. Some candidates used an uncertainty in *m* of 0.5 g or 0.1 g. Candidates should be encouraged to estimate a realistic uncertainty considering both the 1 ml precision scale on the measuring cylinder and the possible loss in transferring the water.

Evaluation

(h) Many candidates gained at least partial credit in this section and the quality of written answers has again improved. Candidates are now more likely to look at the experiment and state what problems they had and offer some solutions. The key to this section is for candidates to identify real problems associated with setting up this experiment and in obtaining the readings. Candidates should be encouraged to ask themselves 'why is this measurement difficult?' Candidates can improve their written answers by suggesting a practical method to use for each problem which would either improve the technique or give more reliable data. In doing this, candidates look at how each solution helps this particular experiment. Candidates most often gained credit for stating that heat is lost to the surroundings, the temperature rises are small and/or the precision of the thermometer is low and the resistor or thermometer bulb is not always completely immersed. Candidates did not gain credit for stating that the temperature varied from place to place in the beaker as it was felt they could have made a reasonable attempt to stir or swill the water. Credit was not awarded for issues such as dealing with the water meniscus in the measuring cylinder or "parallax error" in taking any of the readings, as the solutions are standard laboratory practice that should always be adopted. A comprehensive list of problems and solutions can be found in the mark scheme.

PHYSICS

Paper 9702/41

A2 Structured Questions

Key Messages

- Many candidates would benefit from taking a moment to consider the numerical answers that they have obtained, especially as regards powers of ten. A quick check on whether an answer is 'reasonable' would allow candidates to detect errors in their working.

- Candidates should be encouraged not to 'round off' answers at intermediate stages of a calculation, as this can lead to inaccurate and inappropriate final answers.

- Candidates should be advised to use the data given on page 2 of the question paper. In particular, the use of the approximation $g = 10\,\mathrm{m\,s^{-2}}$ should be discouraged.

- The application of knowledge of basic concepts to unfamiliar situations is often found to be difficult. Candidates who have difficulty would improve their performance if they spent time discussing and practising the application of basic concepts to new situations.

- Most candidates could improve their performance by learning the precise details of definitions and laws required by the syllabus. The wording of answers should relate to the question asked and a certain amount of precision is required at this level. A vague statement of the terms involved is generally not sufficient.

General comments

There were comparatively few scripts where candidates had not attempted to answer all of the questions. There was no real evidence amongst adequately prepared candidates of a shortage of time.

Candidates should be encouraged to read carefully through any question and to note the mark allocation before attempting to answer it. Generally, the mark allocation indicates the required length and complexity of any answer. They should be advised not to commence any answer by writing out large portions of the question. This is very wasteful of valuable time. Furthermore, paraphrasing a question does not assist with any necessary explanation.

Comments on specific questions

Section A

Question 1

(a) This was generally well answered as regards the equations and subsequent algebra. It was not uncommon to find that centripetal force was equated to gravitational attraction without any comment to the effect that the gravitational force provides the centripetal force. This is not an equilibrium situation.

(b)

(i) In general, both parts were completed successfully. The major problems were with powers-of-ten and a failure to convert time in hours to time in seconds. Candidates should be encouraged to consider any answers they obtain. In many instances, a simple error can be detected when an unreasonable answer is seen.

(ii) Most answers were restricted to a comparison of orbital times. Candidates were asked to comment on the orbit and, as such, they could mention that Deimos is almost in a stationary orbit or that Deimos would take a long time to cross the sky.

Question 2

In questions such as this, candidates should distinguish clearly between particles, atoms and molecules.

(a) There were many correct responses, although a significant number mentioned elastic collisions although this aspect was included in the question.

(b)

(i) In **part 1**, there was widespread confusion between number of either molecules or moles. Similarly, in **part 2**, $<c^2>$ was often taken to be the root-mean-square speed.

(ii) There were many clear concise deductions. The main problems were with confusing n and N and, where appropriate, introducing the Boltzmann constant as the ratio R/N_A.

(c)

(i) Most statements included a mention of potential energy and kinetic energy and many associated these energies with molecules. There were comparatively few references to any randomness of the motion of the molecules.

(ii) The majority of answers did include an argument based on the relationship between internal energy, kinetic energy and temperature. Comparatively few made an initial statement to the effect that the potential energy of the molecules is zero because there are no intermolecular forces in an ideal gas.

Question 3

(a)

(i) In most answers, it was recognised that the amplitude is constant. Candidates do need to distinguish between the terms *amplitude* and *displacement*.

(ii) The amplitude decreases gradually and, therefore, the damping is light. A statement to the effect that either the amplitude decreases during a few periods or that the amplitude decreases exponentially is not adequate to distinguish between different forms of damping.

(iii) This determination presented very few problems.

(b)

(i) An adequate statement of this law is known by most candidates. However, they should be advised that an induced e.m.f. does not always give rise to an induced current.

(ii) Many answers indicated a lack of ability to apply concepts to various situations. Crucially, candidates failed to state where the current would be induced. Many were content to invoke Lenz's law without making it clear that the induced current gives rise to a heating effect in the resistance and that this thermal energy is derived from the energy of oscillation of the magnet.

Question 4

(a)

(i) Very few candidates realised that, where static charge is involved, the electric field inside a conductor is zero.

(ii) Most answers did make a reference either to a point where the field strength is zero or to fields in opposite directions. Comparatively few realised that their discussion had to apply to the region between the spheres.

(b)

(i) Responses were generally satisfactory. The use, in this context, of the expression V/x is inappropriate. Candidates should be encouraged to use an expression of the form

$E = (-)\Delta V/\Delta x$.

(ii) The question was concerned with the quantity *rate of change of potential with distance*. Marks in this section were low as a result of candidates considering that this quantity is given by the gradient of the graph. Candidates needed to realise that what was required was the electric field strength.

Question 5

(a) In general, correct expressions were given in both parts. Candidates should be encouraged to use the symbols that are specified in the question.

(b) It should have been noted that the direction of the force due to the electric field must be in the opposite direction to that provided by the magnetic field. Even where this was stated clearly by the candidate, the direction of the magnetic field was often incorrect.

Question 6

(a) In **(i)**, a common error was to assume that the time t_1 represented one period of the oscillation. Most answers for the peak and the r.m.s. voltages were correct. There were very few correct answers for the average voltage, despite the clear waveform shown in Fig. 6.1.

(b) This part was generally well answered. A number of candidates became confused when they attempted to work with peak power. Factor of two errors were frequent.

Question 7

(a) This concept was not understood well, with few responses gaining credit. A common misconception was that each line in the emission spectrum represents an energy level, rather than the energy difference between two levels. Candidates should appreciate that each line represents a photon of specific energy, that the photon is emitted as a result of an energy change of an electron in an atom and, consequently, the specific energy changes arise from changes between discrete energy levels.

(b) Most candidates could identify the correct transition and then go on to calculate the wavelength. In some cases, the energy change was not converted from eV to J.

(c) In most answers, there was a reference to 'lines'. Candidates rarely made clear that a continuous spectrum crossed by dark lines would be observed. Most candidates did realise that only two lines would be seen. The fact that the electrons in the cool gas absorb photons with energies *equal to their excitation energies* was not often made clear.

Question 8

(a)

(i) Candidates do need to learn definitions with care. For half-life, it is the number of nuclei or the activity that is halved. Candidates frequently referred to either the halving of the mass of the sample or to nuclides/atoms/molecules.

(ii) The calculation presented very few problems but candidates should be advised to give full explanation where they are deriving a given answer.

(b) The majority of answers were correct. Some candidates do need further practice with calculations where large numbers are involved, particularly the manipulation of powers-of-ten.

(c) Whether caused by a failure to read carefully the question or whether there was doubt as to what was required by the question, the major difficulty occurred when attempting to determine the number of sulfur-33 nuclei.

Section B

Question 9

(a) The effects could be recalled by most candidates.

(b)

(i) Correct diagrams were in a minority. There was widespread confusion as to the input and many candidates did not show any feedback connection.

(ii) Most answers were correct, with only a minority attempting to use the expression for the gain of an inverting amplifier.

(c) There were relatively few correct lines. Most candidates did show a straight line from (0,0) to (0.60,9.0) but then did not appreciate that the amplifier would saturate with the output remaining at 9.0 V.

(d) Most answers included a reference to the switching of a large current/voltage by means of a small current. Although asked to give some explanation, very few stated that the output on the op-amp circuit would be a few milliamps and could not be used to operate directly any device requiring a large current.

Question 10

(a) Most candidates could give at least two advantages. There was some confusion as regards statements related to 'sending information faster'. Some clearly meant that the signal would travel faster along the cable rather than the increased bandwidth enabling more information to be transmitted in a given time.

(b) Answers where infra-red radiation was identified were in a minority. The lower attenuation per unit length for infra-red when compared with visible light was appreciated by very few. The most common answer was that, whatever radiation was identified, then it would travel faster than visible light.

(c) There were many correct answers here, with very few attempts where the expression for gain in dB was not quoted correctly in some form. Candidates had clearly practised these calculations and this was evident in the number of good responses.

Question 11

(a) Most candidates were able to identify all four blocks but very few answers included satisfactory statements of their functions. It was apparent that, although the names of the blocks could be recalled, their functions, particularly of the switch and the tuning circuit, were not understood. Candidates should be advised not to paraphrase names when explaining functions. For example, block D, identified as being the (a.f.) amplifier, should not then be described as being used 'to amplify the signal'.

(b) This part of the question seemed to take candidates by surprise. Many attempted an answer by reference to communication with the cellular exchange. Where increased bandwidth was mentioned, this was frequently in the context of increased capacity to carry information rather than the availability of more carrier frequencies. The most common acceptable response was short wavelength and, consequently, conveniently short aerials in handsets.

PHYSICS

Paper 9702/42
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PHYSICS

Paper 9702/43

A2 Structured Questions

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- Candidates should be encouraged not to 'round off' answers at intermediate stages of a calculation, as this can lead to inaccurate and inappropriate final answers.
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- Most candidates could improve their performance by learning the precise details of definitions and laws required by the syllabus. The wording of answers should relate to the question asked and a certain amount of precision is required at this level. A vague statement of the terms involved is generally not sufficient.

General Comments

The overall performance of the candidates was similar for **Sections A** and **B** of the paper.

The candidates produced a wide range of responses and the majority of the questions provided good differentiation. The paper successfully challenged the most able candidates, while still providing the weaker candidates with ample opportunity to score marks.

There were comparatively few candidates whose performance over the entire paper was consistently good. Many candidates would benefit from having a deeper understanding of the 'Temperature' section of the syllabus.

There was no evidence that adequately prepared candidates had suffered from a shortage of time to complete their answers.

Comments on Specific Questions

Section A

Question 1

(a)

(i) There were many good answers. A common error was to confuse the diameter of the planet with its radius. Some of the weakest candidates incorrectly calculated the weight using $g = 9.81\,\text{N}\,\text{kg}^{-1}$.

(ii) Although there was a high proportion of good answers, a small minority confused gravitational potential energy with gravitational potential.

(b) This part of the question was reasonably well answered. A significant minority of candidates misunderstood the question and calculated the speed that the rock would have when placed in a circular orbit about the planet.

(c)

(i) Candidates should be encouraged to write down algebraic equations before substitution of the appropriate data. A common error was to fail to square the speed of the molecules when calculating their mean translational kinetic energy.

(ii) The hydrogen molecules have a range of speeds and those with a higher speed can escape at a lower temperature. A few candidates also suggested, quite correctly, that some molecules escape from well above the planet's surface and so these molecules have a higher initial potential energy.

Question 2

(a) There were few correct responses. It was expected that candidates would explain that the temperature scales of the two thermometers are calibrated assuming a linear change in property with temperature. This means that the thermometers will record different temperatures because neither property varies linearly with temperature.

(b) In **(i)** only a small minority of candidates understood that the absolute scale of temperature is different from other temperature scales because it does not depend on the property of any particular substance. However, in part **(ii)**, candidates were more successful in explaining that the absolute zero of temperature is the temperature at which atoms have minimum energy.

(c) Despite being prompted by the question, candidates frequently expressed their answers to an inappropriate number of significant figures. The temperature of the water bath is 323.15 K and its change in temperature is 30.00 K. A common error was to state that the change in temperature is 303.15 K.

Question 3

(a) Candidates should be encouraged to recall precisely all standard definitions in order to avoid ambiguity. Reference should be made to 'displacement' rather than 'distance'.

(b) This part of the question was reasonably well answered, although power-of-ten errors were common.

(c)

(i) Only the most able candidates realised that the reaction force between the cube and the plate is a minimum when the plate is at its maximum displacement above its mean position. This will, therefore, be the position of the plate when the cube just loses contact. Candidates should avoid confusing the terms 'amplitude' and 'displacement' when describing oscillatory motion. A common misconception was that the cube would lose contact at the mean position of the oscillation because that is where the plate has maximum downward velocity.

(ii) Very few candidates realised that the plate would be at its maximum displacement when its acceleration is $9.81\,\text{m}\,\text{s}^{-2}$. Some candidates simply reversed their calculation in part **(b)** to give an incorrect amplitude of 3.0 mm.

Question 4

(a) The most commonly stated function, correctly, was 'energy storage'. It should be noted that capacitors give rise to charge separation, rather than charge storage.

(b)

(i) Many candidates referred to the signs of the charges on the other plates without stating that their magnitudes would be the same as the magnitude of the charge on plate A. Very few answers explained that these charges are observed as a consequence of induction and of charge conservation.

(ii) The syllabus makes direct reference to this derivation and so, as expected, there were many correct answers. However, less able candidates sometimes omitted a key step or attempted to work backwards from the final expression.

(c)

(i) With very few exceptions, a correct answer was given.

(ii) Answers needed to be precise. Energy is dissipated in the resistance of the wires or as a spark at the switch.

Question 5

(a) This part of the question proved to be straightforward for many candidates. However, weaker candidates often failed to take into account the orientation of the network of diodes.

(b) An advantage of bridge rectifiers is that they produce output power on every half-cycle so that there is a greater average power output. Few candidates appreciated this point. Rather, they attempted to involve smoothing.

(c)

(i) It was expected that candidates would state that smoothing is the reduction of the variation of the output voltage or output current.

(ii) The majority of candidates understood that a larger capacitance produces more smoothing for the same load. A common misconception is that the value of the capacitance changes during the smoothing process.

Question 6

(a) It is important that candidates distinguish clearly between the definition of a quantity and that of a unit. The tesla is the unit of magnetic flux density and should be defined in terms of the metre, the newton and the ampere. Candidates need to be encouraged to improve their recall of standard definitions.

(b)

(i) Only a small minority of candidates could explain that the force on the particle is always normal to the direction of motion. This magnetic force provides the centripetal force that is necessary for the particle to move along the arc of a circle. A common error was to state that the force on the particle was always downwards.

(ii) The great majority of answers were correct.

(c)

(i) Although many candidates made reference to the path having a decreasing radius, comparatively few could explain that this was due to the decreasing speed of the particles. Some candidates thought that the particles producing the spiral paths were gamma-ray photons, suggesting a mis-reading of the question stem.

(ii) Where a question asks for a statement with an explanation, candidates should appreciate that, for the award of full credit, the explanation is essential. In **part 1**, the particles must be oppositely charged because the spirals are in opposite directions. Weaker candidates often thought, quite wrongly, that the particles were repelling each other and so must have the same charge. In **part 2**, the particles must have equal initial speeds because their paths have equal initial radii.

Question 7

(a)

(i) Although most answers included a reference to a quantum or ‘packet’ of energy, many did not mention that this was associated with electromagnetic radiation.

(ii) It was expected that candidates would refer to the minimum energy required to remove an electron from the surface of a metal. Of those answers that were recognisable as being concerned with photoelectric emission, many did not include a mention of minimum energy.

(b)

(i) Many candidates were unable to state the photoelectric equation, and would have benefited from further experience of using this equation. A common error was to express one of the terms with an incorrect sign.

(ii) **1.** There were various methods of determining the work function energy. The simplest was to use the value of the *x*-axis intercept from the graph. The most common method involved substituting a pair of values from a point on the graph into the photoelectric equation.

2. Different methods were used to determine a value for the Planck constant. It was expected that candidates would calculate the gradient of the graph and then equate this to $1/hc$. Weaker candidates often made power of ten errors when taking readings from the graph and when using those readings in subsequent calculations. A small minority performed a 'circular' calculation to give the same value of Planck constant that they had previously substituted from the datasheet in their earlier calculation of the work function energy in **part 1**. Such 'circular' calculations were not credited.

Question 8

(a)

(i) Most candidates were able to define the decay constant as being the probability per unit time of the decay of a nucleus. Some answers wrongly made reference to an atom (rather than a nucleus) and to 'probability in unit time' (rather than 'probability per unit time').

(ii) Almost without exception, a correct answer was given.

(b) A significant minority of candidates introduced the Avogadro constant into their calculation when this was not necessary.

Section B

Question 9

(a) The majority of candidates appreciated that the resistance of the LDR increases from daylight to darkness, but comparatively few realised that it increases by a very large factor.

(b)

(i) Most answers were correct.

(ii) Candidates should be encouraged to improve their understanding of comparator circuits. Many were unable to calculate the potential at the non-inverting input. This value is less than the potential at the inverting input and so the output voltage must be negative. Therefore only the green LED will emit light.

(iii) The reduction in light intensity causes an increase in the resistance of the LDR. This increases the potential at the non-inverting input. When this is greater than the potential at the inverting input it will cause the output voltage to 'switch' from negative to positive. Therefore the red LED will now emit light and the green LED will not. A significant number of candidates thought that the change in light intensity at the LDR would cause the brightness of the LEDs to gradually alter and did not appreciate that the output of the operational amplifier saturates at either +9 V or –9 V. Other candidates correctly stated that the red LED would emit light, but omitted to state that the green LED would now not emit light.

Question 10

There were some good explanations, but there were also many low-scoring answers. The most common error was to misinterpret the question and hence not to explain the principles of the generation and detection of ultrasound waves. Explanations of how ultrasound is used to obtain diagnostic information about internal body structures were not credited.

The principles of the generation of ultrasound were reasonably well understood, although comparatively few candidates explained the importance of the dimensions of the piezo-electric crystal in enabling resonance to occur at a frequency in the ultrasound range. The principles of the detection of ultrasound waves were less well understood. When the ultrasound wave is incident on the unstressed piezo-electric crystal, the pressure variations alter the positions of the positive and negative ions within the crystal. Therefore the crystal vibrates so that an alternating potential difference is produced across it which can then be amplified and processed.

Question 11

(a) The majority of candidates appreciated that sharpness is concerned with the ease with which the edges of structures can be determined. However, very few understood that contrast is concerned with the difference in the degree of blackening between different structures. Many descriptions of contrast were either too incomplete or too vague to be awarded any credit.

(b)

(i) Most candidates could recall the correct equation, although arithmetic errors were common.

(ii) This part of the question was effective at differentiating the candidates. A common error was to add, rather than multiply, the individual intensity ratios that correspond to bone and to muscle.

(c) Candidates who stated that the X-ray image was either sharp or not sharp did not receive any credit because it is not possible to judge sharpness from the answers given in part **(b)**. The majority of candidates were able to state the correct contrast of the image.

Question 12

(a) Many answers contained insufficient detail for a question that was worth four marks. The number of marks allocated to a question is a guide to the depth required for the answer. Correct answers tended to fall into one of two categories. The first was that cellular networks enable non-adjacent cells to reuse the same range of <u>carrier frequencies</u> without interference and so the same carrier frequencies can be used by more mobile phone handsets at the same time. The second was that cellular networks allow UHF carrier frequencies to be used because signals at these frequencies have a limited range (line of sight) and allow the handset to have a conveniently short aerial.

(b) The quality of the answers to this part of the question tended to be specific to each Centre. There were some very good answers where the basic facts had been learned. It should be noted that the as the car moves across several cells, the call is switched to the base station with the <u>strongest</u> signal and that this base station may not always be the nearest one to the car.

PHYSICS

Paper 9702/51
Planning, Analysis and Evaluation

Key Messages

- Candidates should be encouraged to read through the whole question paper before starting their answer.
- To gain credit in **Question 1**, candidates must ensure that their answers are detailed and include explanations to answer the question set.
- Graphical work should be carefully attempted and checked. Candidates should use a clear 30 cm ruler.
- To gain credit in the numerical answers towards the end of **Question 2**, it is important that candidates show all their working.
- The skills required for this paper should be developed and practised over a period of time with a 'hands-on' approach.

General Comments

Question 2 was generally answered better than **Question 1** and a large number of candidates scored very highly. It was evident that Centres had spent time on the analysis section enabling their candidates to gain all of the credit available. For **Question 1** candidates should include greater detail in their answers, while for **Question 2** careless mistakes were often made in the plotting of points on the graph. **Question 1** had a number of boxes at the end of the question that are for the Examiner's use; they do also give a useful hint to candidates about the criteria used for awarding credit.

To assist Centres in the preparation of candidates, Cambridge have produced two booklets – Teaching AS Physics Practical Skills and Teaching A2 Physics Practical Skills that are available from the Teacher Support Website.

Comments on Specific Questions

Question 1

Candidates were required to design a laboratory experiment using a Hall probe to investigate how the strength of the magnetic field at the centre of a flat circular coil varies with the radius of the coil.

Initial credit was available for correctly identifying the independent and dependent variables; this was usually answered well. Further credit was then available for stating which other quantities should be kept constant. As indicated in previous reports, the word 'controlled' is not an acceptable alternative to 'constant'. The statements that were required were, 'keep the number of turns on the coil constant' and 'keep the current in the coil constant'. Candidates were able to gain additional detail credit for explaining how the current would be kept constant by using a rheostat and an ammeter. Statements such as 'use an ammeter to measure the current' did not gain credit; the idea of checking the current to ensure it was constant was required for the award of credit.

Credit was also available for the methods of data collection. Candidates are expected to draw a diagram of the arrangement of their equipment suitable for this investigation. Diagrams should be clearly labelled. Many of the diagrams did not indicate the Hall probe at the centre of a flat coil; often solenoids were drawn or the Hall probe was along an axis from the coil. Candidates were expected to draw a circuit diagram to indicate how the coil was connected to a d.c. power supply. Incorrect circuit diagrams often contained voltmeters connected in series with ammeters; correct symbols should be used. Credit was available for the output of the Hall probe and for determining the diameter and hence radius of the coil by using a ruler or vernier calipers; additional detail credit was awarded for repeating the measurements of the radius and finding the mean. There was also credit available for finding the centre of the coil. A number of candidates suggested good methods.

Credit was available for the analysis of the data. It is expected that candidates would state the quantities that should be plotted on each axis of a graph; many candidates suggested plotting a graph of B against $1/r$; other logically valid graphs were credited. A large number of candidates incorrectly suggested plotting a graph of B against r and then stated that the negative gradient of this graph confirms the inverse proportionality. Further credit was available for explaining that the relationship would be valid if a straight line passing through the origin was produced—this needed to be explicitly stated and credit was not given for a sketch graph. Some candidates suggested plotting a graph of lg B against lg r which gained credit. To gain further credit in this case, candidates would need to state that the relationship would be valid if a straight line of gradient equal to minus one was produced.

Credit was available for describing an appropriate safety precaution. Candidates should be encouraged to ensure that safety precautions are relevant to the experiment and are clearly reasoned; vague answers did not gain credit. Credit-worthy responses linked the heat generated in the coil to an appropriate precaution. Credit was not awarded for references to wires—heating of the coils was essential.

As already mentioned, credit is available for additional detail. Candidates should be encouraged to write their plans including appropriate detail; often candidates' answers lacked sufficient practical experience. Vague responses did not score. In addition to the points already mentioned above, credit was also given for:

- the use of a large current (or large number of turns on coils) to produce large magnetic fields,
- keeping the Hall probe at right angles to the direction of the magnetic field,
- a method to ensure that the Hall probe had a constant orientation,
- the strength of the magnetic field being directly proportional to the Hall voltage,
- repeating the experiment with the direction of the Hall probe reversed.

Usually, more able candidates who have followed a 'hands on' practical course during their studies gain additional detail credit. It is essential that candidates' answers give detail relevant to the experiment in the question rather than 'text book' rules for working in a laboratory.

Question 2

In this data analysis question, candidates were given data concerning the orbits of six moons around Jupiter.

(a) A significant number of candidates found this difficult with many ignoring the squaring in T^2.

(b) Candidates should be advised that for logarithmic quantities the number of significant figures corresponds to the number of decimal places in the logarithmic quantity. It is expected that the number of significant figures in calculated quantities should be the same as or one more than the number of significant figures in the raw data. Thus when *r* has a value of 129×10^6 m which is three significant figures, lg (*r* / m) should be given to either 8.111 (three decimal places) or 8.1106 (four decimal places). The absolute uncertainties in lg *T* were usually calculated correctly. The Examiners allowed different methods for finding uncertainties and did not penalise significant figures at this stage.

(c)

(i),**(ii)** The graph plotting was quite variable. Common mistakes included not plotting the points correctly (particularly the point at 8.63 or 8.83 which were often half a small square out by being plotted at 8.62 and 8.82 respectively). Candidates should be encouraged to check plots that do not appear to follow the line of best fit. Similarly a number of candidates did not construct the error bars accurately. Most candidates attempted to draw the line of best fit. The worst acceptable straight line should be either the steepest possible line or the shallowest possible line that passes through the error bars of all the data points used for the line of best fit. The majority of the candidates labelled clearly the lines on their graph; in future, lines not indicated may not be credited. A number of candidates did not gain credit for their lines since they were not straight. In many cases it would appear that the candidates were using a 15 cm ruler and thus having in effect to draw two lines (often so that the resulting line was not straight); candidates should be encouraged to use a clear 30 cm ruler.

(iii) This was generally answered well, although candidates could often make their working clearer. Some candidates did not use a sensibly-sized triangle for their gradient calculation. To determine the absolute error in the gradient, candidates were expected to find the difference between the gradient of the line of best fit and the gradient of the worst acceptable line. A large number of able candidates clearly indicated the points that they have used from the line of best fit.

(iv) A large number of candidates did not realise that there was a false origin. More able candidates substituted a point from the line of best fit (often from their gradient calculation) into $y = mx + c$. To determine the uncertainty in the *y*-intercept, candidates had to determine the worst acceptable *y*-intercept by using the gradient from the worst acceptable line and a point on the worst acceptable line. Some candidates did not gain credit since they just used 3/2 for the gradient rather than the answer to **(c)(iii)**. Other candidates determined lg *k* rather than the *y*-intercept. Ratio methods cannot be used to find the uncertainty in the *y*-intercept.

(d)

(i) Candidates needed to determine *k* by using their value for the *y*-intercept. Many candidates clearly showed their working and did this correctly. A common error was not multiplying the *y*-intercept by two. Substitution methods did not score. To determine the uncertainty in *k*, many candidates tried incorrectly to use a ratio method. Candidates should be encouraged to clearly show their working at this stage.

(ii) Candidates needed to determine the mass of Jupiter. Credit awarded here is for quality, for candidates who have carefully worked through the paper. More able candidates clearly showed their working. It was hoped that candidates who gained answers of the order of 2000 kg (or less) would have reviewed their working earlier in the question. On this and all other papers for 9702, candidates should be encouraged to check whether the answers they obtain are of a reasonable order of magnitude.

PHYSICS

Paper 9702/52

Planning, Analysis and Evaluation

Key Messages

- Candidates should be encouraged to read through the whole question paper before starting their answer.
- To gain credit in **Question 1**, candidates must ensure that their answers are detailed and include explanations to answer the question set.
- Graphical work should be carefully attempted and checked. Candidates should use a clear 30 cm ruler.
- To gain credit in the numerical answers towards the end of **Question 2**, it is important that candidates show all their working.
- The skills required for this paper should be developed and practised over a period of time with a 'hands-on' approach.

General Comments

Question 2 was generally answered better than **Question 1** and a large number of candidates scored very highly. It was evident that Centres had spent time on the analysis section enabling their candidates to gain all of the credit available. For **Question 1** candidates should include greater detail in their answers, while for **Question 2** careless mistakes were often made in the plotting of points on the graph. **Question 1** had a number of boxes at the end of the question that are for the Examiner's use; they do also give a useful hint to candidates about the criteria used for awarding credit.

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Candidates were required to design a laboratory experiment using a Hall probe to investigate how the strength of the magnetic field at the centre of a flat circular coil varies with the radius of the coil.

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Credit was also available for the methods of data collection. Candidates are expected to draw a diagram of the arrangement of their equipment suitable for this investigation. Diagrams should be clearly labelled. Many of the diagrams did not indicate the Hall probe at the centre of a flat coil; often solenoids were drawn or the Hall probe was along an axis from the coil. Candidates were expected to draw a circuit diagram to indicate how the coil was connected to a d.c. power supply. Incorrect circuit diagrams often contained voltmeters connected in series with ammeters; correct symbols should be used. Credit was available for the output of the Hall probe and for determining the diameter and hence radius of the coil by using a ruler or vernier calipers; additional detail credit was awarded for repeating the measurements of the radius and finding the mean. There was also credit available for finding the centre of the coil. A number of candidates suggested good methods.

Credit was available for the analysis of the data. It is expected that candidates would state the quantities that should be plotted on each axis of a graph; many candidates suggested plotting a graph of B against $1/r$; other logically valid graphs were credited. A large number of candidates incorrectly suggested plotting a graph of B against r and then stated that the negative gradient of this graph confirms the inverse proportionality. Further credit was available for explaining that the relationship would be valid if a straight line passing through the origin was produced—this needed to be explicitly stated and credit was not given for a sketch graph. Some candidates suggested plotting a graph of lg B against lg r which gained credit. To gain further credit in this case, candidates would need to state that the relationship would be valid if a straight line of gradient equal to minus one was produced.

Credit was available for describing an appropriate safety precaution. Candidates should be encouraged to ensure that safety precautions are relevant to the experiment and are clearly reasoned; vague answers did not gain credit. Credit-worthy responses linked the heat generated in the coil to an appropriate precaution. Credit was not awarded for references to wires—heating of the coils was essential.

As already mentioned, credit is available for additional detail. Candidates should be encouraged to write their plans including appropriate detail; often candidates' answers lacked sufficient practical experience. Vague responses did not score. In addition to the points already mentioned above, credit was also given for:

- the use of a large current (or large number of turns on coils) to produce large magnetic fields,
- keeping the Hall probe at right angles to the direction of the magnetic field,
- a method to ensure that the Hall probe had a constant orientation,
- the strength of the magnetic field being directly proportional to the Hall voltage,
- repeating the experiment with the direction of the Hall probe reversed.

Usually, more able candidates who have followed a 'hands on' practical course during their studies gain additional detail credit. It is essential that candidates' answers give detail relevant to the experiment in the question rather than 'text book' rules for working in a laboratory.

Question 2

In this data analysis question, candidates were given data concerning the orbits of six moons around Jupiter.

(a) A significant number of candidates found this difficult with many ignoring the squaring in T^2.

(b) Candidates should be advised that for logarithmic quantities the number of significant figures corresponds to the number of decimal places in the logarithmic quantity. It is expected that the number of significant figures in calculated quantities should be the same as or one more than the number of significant figures in the raw data. Thus when *r* has a value of 129×10^6 m which is three significant figures, lg (*r* / m) should be given to either 8.111 (three decimal places) or 8.1106 (four decimal places). The absolute uncertainties in lg *T* were usually calculated correctly. The Examiners allowed different methods for finding uncertainties and did not penalise significant figures at this stage.

(c)

(i),**(ii)** The graph plotting was quite variable. Common mistakes included not plotting the points correctly (particularly the point at 8.63 or 8.83 which were often half a small square out by being plotted at 8.62 and 8.82 respectively). Candidates should be encouraged to check plots that do not appear to follow the line of best fit. Similarly a number of candidates did not construct the error bars accurately. Most candidates attempted to draw the line of best fit. The worst acceptable straight line should be either the steepest possible line or the shallowest possible line that passes through the error bars of all the data points used for the line of best fit. The majority of the candidates labelled clearly the lines on their graph; in future, lines not indicated may not be credited. A number of candidates did not gain credit for their lines since they were not straight. In many cases it would appear that the candidates were using a 15 cm ruler and thus having in effect to draw two lines (often so that the resulting line was not straight); candidates should be encouraged to use a clear 30 cm ruler.

(iii) This was generally answered well, although candidates could often make their working clearer. Some candidates did not use a sensibly-sized triangle for their gradient calculation. To determine the absolute error in the gradient, candidates were expected to find the difference between the gradient of the line of best fit and the gradient of the worst acceptable line. A large number of able candidates clearly indicated the points that they have used from the line of best fit.

(iv) A large number of candidates did not realise that there was a false origin. More able candidates substituted a point from the line of best fit (often from their gradient calculation) into $y = mx + c$. To determine the uncertainty in the *y*-intercept, candidates had to determine the worst acceptable *y*-intercept by using the gradient from the worst acceptable line and a point on the worst acceptable line. Some candidates did not gain credit since they just used 3/2 for the gradient rather than the answer to **(c)(iii)**. Other candidates determined lg *k* rather than the *y*-intercept. Ratio methods cannot be used to find the uncertainty in the *y*-intercept.

(d)

(i) Candidates needed to determine *k* by using their value for the *y*-intercept. Many candidates clearly showed their working and did this correctly. A common error was not multiplying the *y*-intercept by two. Substitution methods did not score. To determine the uncertainty in *k*, many candidates tried incorrectly to use a ratio method. Candidates should be encouraged to clearly show their working at this stage.

(ii) Candidates needed to determine the mass of Jupiter. Credit awarded here is for quality, for candidates who have carefully worked through the paper. More able candidates clearly showed their working. It was hoped that candidates who gained answers of the order of 2000 kg (or less) would have reviewed their working earlier in the question. On this and all other papers for 9702, candidates should be encouraged to check whether the answers they obtain are of a reasonable order of magnitude.

PHYSICS

Paper 9702/53
Planning, Analysis and Evaluation

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- To gain credit in the numerical answers towards the end of **Question 2**, it is important that candidates show all their working.
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Question 2 was generally answered better than **Question 1** and a large number of candidates scored very highly. It was evident that Centres had spent time on the analysis section enabling their candidates to gain all of the credit available. For **Question 1** candidates should include greater detail in their answers, while for **Question 2** careless mistakes were often made in the plotting of points on the graph. **Question 1** had a number of boxes at the end of the question that are for the Examiner's use; they do also give a useful hint to candidates about the criteria used for awarding credit.

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Comments on Specific Questions

Question 1

Candidates were required to design a laboratory experiment to investigate how the e.m.f. in a secondary coil depends on the cross-sectional area of a primary coil.

Initial credit was awarded for correctly identifying the independent and dependent variables, and this was frequently answered well. Credit was then available for stating which other quantities should be kept constant. As indicated in previous reports, the word 'controlled' is not an acceptable alternative to 'constant'. The statements that were required were 'keep the number of turns on each coil constant' and 'the alternating current flowing in the primary coil (X) should be kept constant'. Candidates choosing to use a signal generator could also gain further credit for stating that the frequency of the supply should be kept constant.

Credit was available for the methods of data collection. Candidates are expected to draw a diagram of the arrangement of their equipment suitable for this investigation. Many of the diagrams did not distinguish between the two separate coils X and Y. Diagrams should be clearly labelled and circuit diagrams should use appropriate symbols. Incorrect circuit diagrams often contained voltmeters connected in series with ammeters or the symbol for a d.c. battery instead of an a.c. power supply. Credit was available for the method of finding the cross-sectional area of the combined coils; firstly for using a rule or vernier calipers to find the average diameter and secondly for giving the correct formula for the area; a micrometer screw gauge was not credited. Both circular and rectangular tubes were credited; however, many candidates confused the term cross-sectional area with surface area of the tube.

Credit was also available for the analysis of the data. It is expected that candidates would state the quantities that should be plotted on each axis of a graph; many candidates suggested plotting a graph of V against A; other logically valid graphs were credited. Credit was then awarded for explaining that the relationship would be valid if a straight line passing through the origin was produced – this needed to be explicitly stated and credit was not given for a sketch graph. Some candidates suggested plotting a graph of lg V against lg A which gained credit. To gain further credit in this case, candidates would need to state that the relationship would be valid if a straight line of gradient equal to one was produced.

Credit was available for describing an appropriate safety precaution. Candidates should be encouraged to ensure that the safety precaution(s) is/are relevant to the experiment and clearly reasoned; vague answers did not gain credit. Credit-worthy responses linked the heat generated in the coil to an appropriate precaution. Credit was not awarded for references to wires—heating of the coils was essential.

Further credit was available for additional detail. Candidates should be encouraged to write their plans including appropriate detail; often candidates' answers lacked sufficient practical detail. Vague responses did not score. In addition to the points already mentioned above, credit was also given for:

- the use of high currents (or large number of turns on coils, or high frequency a.c.) to produce measurable e.m.f.,
- taking many readings of the diameter (or width) of the cardboard tube along its length and then obtaining an average value,
- the use of an ammeter to monitor and a rheostat to maintain constant current in coil X,
- a reasoned explanation of the measurement of e.m.f. using a c.r.o. e.g. height of trace multiplied by *y*-gain (some candidates confused 'time base' with *y*-gain.).

Many candidates realised the problems associated with adjacent magnetic fields, but very few went on to say that alternating magnetic fields should be avoided.

Usually, more able candidates who have followed a 'hands on' practical course during their studies gain credit for additional detail. It is essential that candidates' answers give detail relevant to the experiment in the question rather than 'text book' rules for working in a laboratory.

Question 2

In this data analysis question, candidates were given data concerning the motion of a trolley.

(a) This was generally well answered.

(b) Most candidates correctly completed the table of results, finding values for *m*/(*m*+*M*) and v^2 and its uncertainty. Many candidates recorded their values to an appropriate number of significant figures; some reduced the mass ratio column to only two significant figures. It is expected that the number of significant figures in calculated quantities should be the same as or one more than the number of significant figures in the raw data. The absolute uncertainties in v^2 were usually calculated correctly, although there were a small number of 'power of ten' errors; the Examiners allowed different methods for finding uncertainties and did not penalise significant figures at this stage

(c)

(i),**(ii)** The graph plotting was quite variable. Common mistakes included not plotting the points correctly (particularly the point at 0.333 for the mass ratio which was often plotted at 0.33); candidates should be encouraged to check plots that do not appear to follow the line of best fit. Most candidates attempted to draw the line of best fit. The worst acceptable straight line should be either the steepest possible line or the shallowest possible line that passes through the error bars of all the data points used for the line of best fit. Because of severe rounding of uncertainty data, some candidates found that the worst acceptable line did not pass through the ends of the top error bar. The Examiners were able to treat most of these cases as "error carried forward". The majority of the candidates labelled clearly the lines on their graph; in future lines not indicated may not be credited. A number of candidates did not gain credit for their lines since they were not straight. In many cases it would appear that the candidates were using a 15 cm ruler and thus having in effect to draw two lines (often so that the resulting line was not straight); candidates should be encouraged to use a clear 30 cm ruler.

(iii) This was generally answered well, although candidates could often make their working clearer. Some candidates did not use a sensibly-sized triangle for their gradient calculation. To determine the absolute error in the gradient candidates were expected to find the difference between the gradient of the line of best fit and the gradient of the worst acceptable line. A large number of good candidates clearly indicated the points that they used from the line of best fit.

(d) Most candidates gained credit for correctly using their expression for gradient from **(a)**. Substitution methods did not score. Credit for the absolute uncertainty in *g* could be obtained either from the gradient of the graph and its uncertainty or from the difference between the value for *g* and its maximum value. Many candidates did this correctly.

(e) Candidates needed to find the largest possible value for velocity *v* when the mass of the trolley was increased by one kilogram and to include the absolute uncertainty. The mass ratio for this becomes 0.25, and then there are several ways to find the value of *v*. Many candidates gained credit here.

Candidates were able to use any appropriate method to determine the absolute uncertainty in this value of *v.* More able candidates used the uncertainty in their value for *g*, the uncertainty in their gradient value, or the difference derived from their best and worst values of *v*.