

Examiners' Report
June 2018

GCE Physics 9PH0 03

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June 2018

Publications Code 9PH0_03_1806_ER

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Introduction

This paper consists of 120 marks split between short open, open-response, calculations and extended writing questions. The questions draw on a range of the topics in the specification, and include synoptic questions drawing on two or more different topics. The paper also includes questions that assess conceptual and theoretical understanding of experimental methods (indirect practical skills), some of which draw on students' experiences of the core practicals.

The paper gave students the opportunity to demonstrate their understanding of a wide range of topics from the specification, with all of the questions eliciting responses across the range of marks. Some question types that produced poor responses in June 2017 have resulted in better responses in this examination, demonstrating that students are improving in their ability to answer new style questions as their exposure to such questions increases.

However, the marks for questions Q1, Q2a, Q4, Q7b, Q9b, and Q13b, which test indirect practical skills, tended to be clustered at the lower end of the scale. Similarly Q10c, Q12a, which are linkage questions, and questions Q6b, Q8b and Q13c which are synoptic/synthesis questions, tended not to be as well answered as other questions on the paper.

On the whole, linkage questions in this paper tended to be poorly answered, with students either not giving enough detail for a question with 6 indicative content points, or failing to link the ideas adequately. Similarly, questions that require students to "assess", "discuss", "criticise" etc. are producing superficial responses that omit essential physics theory. Many students seem to be focusing on coming to a conclusion, rather than justifying how that conclusion might be supported by the evidence.

As with the Legacy specification (GCE 2008), calculation and 'show that' questions gave students an opportunity to demonstrate their problem solving skills to good effect. Some very good responses were seen for such questions, with well crafted, solutions which were accurate and clearly set out. Occasionally in calculation questions the final mark was not awarded due to a missing unit.

There were examples of students disadvantaging themselves by not actually answering the question, or by not expressing themselves using suitably precise language. This was particularly the case in some of the questions testing indirect practical skills such as 7b and 9b, where students sometimes had knowledge of the method, but could not express it accurately and succinctly. Students could most improve by ensuring they understand all aspects in sufficient detail and always use appropriate specialist terminology when giving descriptive answers.

Scientific terminology was used imprecisely and incorrectly in a number of responses seen on this paper. Voltage was sometimes used instead of specifying e.m.f. or potential difference, and whether to refer to decimal places or the number of significant figures in a practical context was often poorly understood.

Students need further practice in applying knowledge and skills to novel practical situations. Some of the language of and processes of quantifying uncertainties in practical work is poorly understood by students. In particular candidates' use of the terms accuracy, error, precision, resolution and uncertainty.

The space allowed for responses was usually sufficient. However, students need to remember that the space provided does not have to be filled. Students should be encouraged to consider the number of marks available for a question, and to use this to inform their response. If students either need more space or want to replace an answer with a different one, they should indicate clearly where that response is to be found.

Question 1

This question relies upon an understanding of the definitions of **accuracy** and **precision**. The terms used in this specification are those described in the publication by the Association for Science Education entitled The Language of Measurement. It should be noted that certain terms have a meaning different from those in the Legacy specification. For further detail, refer to Appendix 10 of the current specification document.

In part (a), although many students correctly identified accuracy as how close a measured value is to the true value, a significant minority of students confused precision with resolution of an instrument. When students were aware that precision is due to the consistency of values they often omitted that these values needed to be obtained by repeated measurements. In (b) a significant number of students were able to say that the value was not accurate because of a systematic error such as a zero error, calibration error or parallax error. Many students omitted to say whether their descriptions referred to precise or accurate values.

- 1 A practical physics textbook states that “measurements may give a precise value for the quantity being determined but this may not necessarily be an accurate value”.

(a) Describe what physicists mean by the terms accuracy and precision.

(2)

Precision is how many significant figures the measurements would give,
so

Accuracy is how close to the actual value the measurement is

- (b) The temperature of the air in a room is measured using a mercury-in-glass thermometer.

Describe how the value for the temperature may be precise but not accurate.

(2)

There could be a scale on the thermometer which is precise to 1°C , or less, which would be precise, but if that value is not very close to the real air temperature, e.g. if the room is being rapidly heated, ~~but~~ the thermometer hasn't adjusted yet, then it would not be accurate.



In this response precision is confused with resolution.



Learn definitions of key terms given in the specification so that you can write accurate descriptions in the examination.

- 1 A practical physics textbook states that “measurements may give a precise value for the quantity being determined but this may not necessarily be an accurate value”.

(a) Describe what physicists mean by the terms accuracy and precision.

(2)

accuracy: how close the experimental value is to the true value

precision: how close repeat readings are to each other.

- (b) The temperature of the air in a room is measured using a mercury-in-glass thermometer.

Describe how the value for the temperature may be precise but not accurate.

(2)

a mercury-in-glass thermometer can be well calibrated which reduces any systematic errors which improves precision. However, random errors can still occur which reduce the accuracy of the measurement.



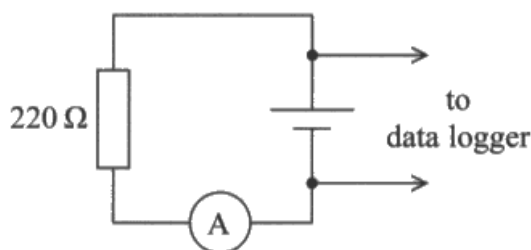
In this response accuracy and precision are correctly defined in part (i), but in part (ii) systematic error is linked to precision rather than accuracy.

Question 2 (a)

This question required students to state why a data logger would be suitable in this investigation. The responses seen would tend to indicate that many students had learned some generic advantages of using a data logger without considering how relevant these would be for the stated investigation.

The answer expected was that the data had to be collected over a long time. However, very few realised the significance of the length of time involved. A significant number of candidates said in answer to this question that data loggers were able to take many readings in a short time period or that reaction time didn't have to be taken into consideration. The prevalence of responses that repeated standard advantages of using data loggers rather than considering the specific experiment referred to in the question meant that very few candidates were awarded this mark.

- 2 A student is investigating how the internal resistance of a dry cell varies over time. She sets up the circuit shown to draw current from the cell.



The student proposes to use a data logger to monitor the terminal potential difference (p.d.) of the cell over a period of time.

- (a) State why a data logger would be suitable to collect data in this investigation.

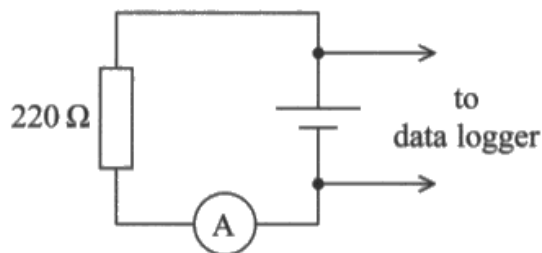
(1)

The Datalogger can plot an automatic graph for us



This response is typical of many seen. Although it may be an advantage to the experimenter that the graph is plotted automatically, this is not a good reason for why a data logger should be used.

- 2 A student is investigating how the internal resistance of a dry cell varies over time. She sets up the circuit shown to draw current from the cell.



The student proposes to use a data logger to monitor the terminal potential difference (p.d.) of the cell over a period of time.

- (a) State why a data logger would be suitable to collect data in this investigation.

(1)

- It can take a lot of readings in short time intervals without relying on human reaction time.



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Examiner Comments

In some applications, these would be reasons for choosing a data logger. However, in this application the time interval is not short, and reaction time is not an issue.



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Examiner Tip

Always relate answers to the context given in the question.

Question 2 (b) (i)

This question tested students' understanding of e.m.f. and terminal potential difference.

Although a few students referred to voltage, the majority of students did use the term 'potential difference' in their answers thereby gaining MP1. However, a significant number failed to mention that the (external) resistance in the circuit remained constant and so were not awarded MP2. Some students tried unsuccessfully to answer this question by stating that the current would reduce due to a decrease in the energy per unit charge flowing through the cell over the lifetime of the cell.

- (i) Explain, using the graph, why the current drawn from the cell decreases as the chemical energy store in the cell is depleted.

(2)

Because the potential difference across the cell is decreasing as chemical energy store is depleted.
As $V = IR$, as V decreases, so does current.



This response correctly states that the potential difference across the cell is decreasing as the chemical energy store is depleted, but they omit to say that the resistance in the circuit remains constant for MP2.

- (i) Explain, using the graph, why the current drawn from the cell decreases as the chemical energy store in the cell is depleted.

(2)

The resistance in the circuit is constant, as the percentage of chemical energy depleted rises, the terminal ~~is~~ p.d. falls.
As $V = IR$, as ~~this is const~~ R is constant, a fall in p.d. will lead to a fall in current.

Although the language used in this response is quite awkward, there is enough for both marking points to be awarded.

Question 2 (b) (ii)

Nearly all students were able to use the graph to obtain a suitable value for the potential difference. However, a significant minority used the e.m.f. with the external resistance to calculate an incorrect value for the current. Some students failed to realise that the current is the same for R and r . Some students appeared reluctant to use decimals and did most of the calculations with fractions. This sometimes led to arithmetic errors. The unit was sometimes omitted from the final answer.

- (ii) Determine the internal resistance of the cell when its chemical energy store is 80% depleted. Assume that the e.m.f. of the cell remains constant at 4.0 V.

(3)

$$E = V + Ir.$$

$$3.5V$$

$$4 = 3.5 + Ir.$$

$$0.5 = Ir.$$

$$r = \frac{0.5}{\frac{3.5}{220}}$$

$$I = \frac{3.5}{220}$$

$$= 31.43 \Omega$$

Internal resistance = 31.43 Ω

This response scores all 3 marks.

- (ii) Determine the internal resistance of the cell when its chemical energy store is 80% depleted. Assume that the e.m.f. of the cell remains constant at 4.0 V.

(3)

When 80% depleted 3.52 V left

~~$E = I r + I R$~~

~~$4/7$~~

$$I = \frac{V}{R}$$

$$= \frac{4}{20} = \frac{1}{5} \text{ A}$$

$$E = I r + I R$$

$$\frac{4 - 3.52}{\frac{1}{5}} = r$$

$$r = 26.4 \Omega$$

Internal resistance = 26.4 Ω



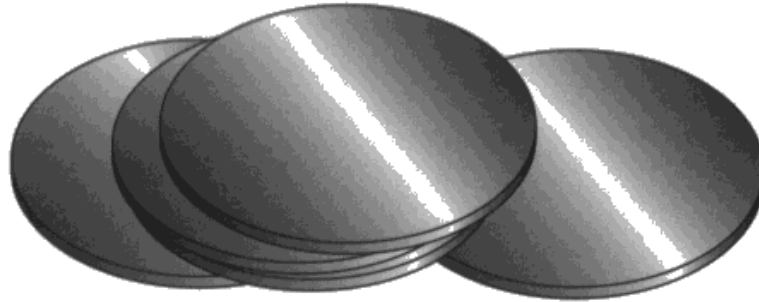
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Examiner Comments

In this response the circuit current has been calculated by assuming that the e.m.f. rather than the terminal p.d. of the cell is across the resistor. Hence the final answer is incorrect and out of range.

Question 3 (a)

The majority of students correctly identified the micrometer as a suitable measuring instrument. Some mentioned digital calipers which was acceptable, but a common incorrect answer was vernier calipers.

3 A student is investigating the properties of steel. He has fifty steel discs available.



Each disc has a diameter $d \approx 1.3$ cm and a thickness $t \approx 2$ mm.

(a) State a suitable measuring instrument that could be used with a single disc to measure t .
(1)

vernier calliper



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Examiner Comments

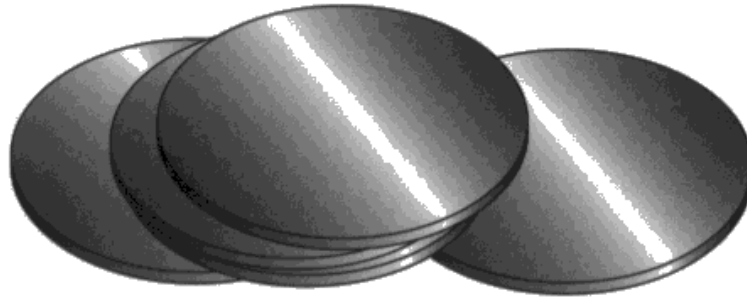
This was a common wrong answer. However, digital calipers would be suitable, as they have a higher resolution than vernier calipers.



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Examiner Tip

Consider the resolution of all the measuring instruments available to allow the most suitable instrument to be selected.

3 A student is investigating the properties of steel. He has fifty steel discs available.



Each disc has a diameter $d \approx 1.3$ cm and a thickness $t \approx 2$ mm.

(a) State a suitable measuring instrument that could be used with a single disc to measure t .

(1)

micrometer
A screw gauge can be used here.



In this response "screw gauge" on its own would not be enough to score for the mark. However, "micrometer" has been added in front of screw gauge and so the mark can be awarded.

Question 3 (b)

Most students were able to calculate the volume and the mass of a disc. However, a common mistake was to divide the resolution (0.2) instead of the uncertainty (0.1) by the percentage uncertainty of 0.5% to find the total mass needed. A common method seen was to try to use trial and improvement to find the correct number of disks. Applied correctly this could score full marks. However, many responses of this type were incomplete.

(b) A balance which can measure mass with a resolution of 0.2 g is available.

Determine the minimum number of discs that should be placed on the balance together if the percentage uncertainty in the measurement of the mass is to be less than 0.5%.

(4)

density of steel = 7900 kg m^{-3}

$$\begin{aligned} \text{volume of one disk} &= \pi r^2 h \\ &= \pi \times (0.65 \times 10^{-2})^2 \times 2 \times 10^{-3} \\ &= 2.65 \times 10^{-7} \text{ m}^3 \end{aligned}$$

$$\text{uncertainty of mass} = \pm 0.1 \text{ g}$$

α

$$0.5 = \frac{0.1}{x} \times 100$$

$$x = 20 \text{ g}$$

$$x = 20 \times 10^{-3} \text{ kg}$$

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

$$7900 = \frac{20 \times 10^{-3}}{V}$$

$$V = 2.53 \times 10^{-6} \text{ m}^3$$

$$\frac{2.53 \times 10^{-6}}{2.65 \times 10^{-7}} = 9.55 \text{ minimum number } 10$$

Minimum number of discs =



ResultsPlus
Examiner Comments

This response scored all 4 marks.

(b) A balance which can measure mass with a resolution of 0.2 g is available.

Determine the minimum number of discs that should be placed on the balance together if the percentage uncertainty in the measurement of the mass is to be less than 0.5%.

(4)

density of steel = 7900 kg m^{-3}

$$V = \frac{4}{3}\pi r^3 \quad r = 0.65 \text{ cm} = 0.0065 \text{ m} \quad t = 0.002 \text{ m}$$

$$V = \frac{4}{3}\pi r^3 h$$

$$= \frac{4}{3}\pi (0.0065)^3 (0.002)$$

$$= 3.5 \times 10^{-7} \text{ m}^3$$

$$7900 \times 0.00000035 = 2.765$$

$$7900 \times 3.5 \times 10^{-7} = 2.765 \times 10^{-3} \text{ kg}$$

$$= 2.765 \text{ g}$$

$$\frac{0.2}{2.765} \times 100 = 7.23\%$$

$\therefore 15$ discs

Minimum number of discs = 15



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Examiner Comments

In this response the volume of the disc is incorrectly calculated, as the expression for the volume of a sphere has been used. Although the equation is not written down, it is clear that this incorrect volume has been used with the density to calculate a value for the mass of the disc and so MP2 can be given. The resolution has been used to calculate a percentage with a random number of 15 discs to give a percentage lower than 0.5%. It is likely that a trial and improvement method is being used, but in this case the method is incomplete.



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Examiner Tip

Learn the expressions for volumes of regular objects so that you don't confuse the volume of a cylinder with the volume of a sphere.

Question 3 (c)

This question assesses students' ability to calculate and combine uncertainties.

The percentage uncertainties in diameter and thickness were often correctly calculated, however some calculated the percentage uncertainty in the radius which was incorrect. Multiplying the percentage uncertainty in the diameter by two to find the percentage uncertainty in the area was usually seen in the majority of answers. Many students round up too early in their calculations, which can give an inaccurate answer. Some tried to calculate maximum/minimum values for volume and then calculating the percentage uncertainty in the final answer from these values. The final answer was expected to be given to no more than two significant figures.

- (c) The measured uncertainty in d is ± 0.1 mm and the measured uncertainty for t is ± 0.05 mm.

Determine the percentage uncertainty in the calculated volume of the disc.

(3)

$$\frac{0.1}{13} \times 100 = 0.77\%$$

$$\frac{0.05 \times 10^{-9}}{2 \times 10^{-3}} \rightarrow \frac{0.05}{2} \times 100 = 2.5\%$$

$$\text{Percentage uncertainty} = 0.77 \times 2 + 2.5 = 4.04\%$$



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Examiner Comments

This response would score full marks if the final answer were to be given to 1 or 2 significant figures rather than 3.



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Examiner Tip

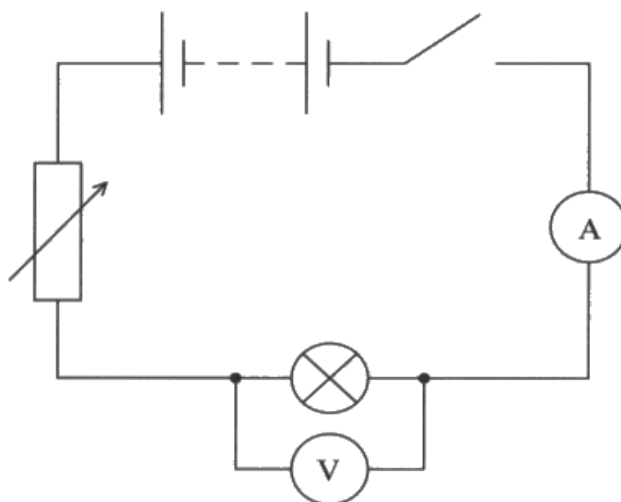
When calculating uncertainties, remember that these are estimates. Final answers for uncertainties should be given to 1 or 2 significant figures.

Question 4 (a)

In this context “criticise” means that inconsistencies in the recording of the data should be commented upon. However, some students commented upon the data collection rather than the data recording.

The most common answer given was that current values should all be recorded to the same number of significant figures. The correct answer, which was less commonly seen, was that the current values should be recorded to the same number of decimal places or to the same resolution. When dealing with raw data the resolution of the instrument being used (and hence the number of decimal places quoted) is key. The number of significant figures quoted for raw data may, but does not have to be, consistent.

- 4 A student set up the circuit shown and measured the current I through the filament lamp for a range of values of potential difference (p.d.) V .



The student's data is shown in the table.

V/V	I/A
3.0	0.6
4.0	0.75
6.0	1.00
8.0	1.20
10.0	1.35
12.0	1.5

- (a) Criticise the student's recording of the data.

(1)

the results are not all to the same
number of decimal places



This is a correct response.

(a) Criticise the student's recording of the data.

(1)

Not to the same number of significant figures and not the same intervals between readings.



This response is incorrect, as it identifies the same number of significant figures rather than the same number of decimal places. In addition, there is a comment about the data collection, rather than the data recording. This was seen relatively often, but did not score a mark.



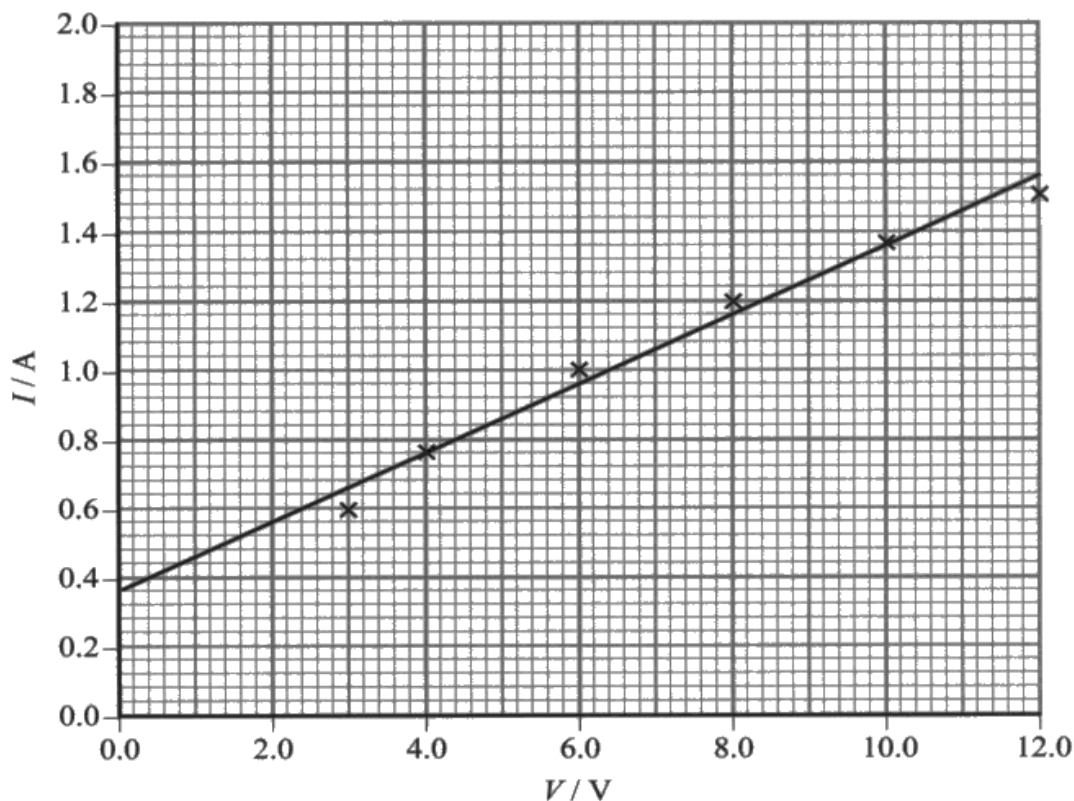
Read the question carefully to ensure that your response is an answer to the question.

Question 4 (b)

This item required students to “assess the validity” of a statement, which requires students to draw a conclusion from the information provided. Hence it is vital for full marks that students bring the two pieces of evidence together to make a conclusion that refers to Ohm’s law.

Many correctly stated that Ohm’s law required current to be directly proportional to p.d., so the line should pass through the origin if the law was to be obeyed. They then went on to say that as the line didn’t pass through the origin then the student’s statement was not valid. Few said that the correct line should be a curve or that, as the question was about a filament lamp, the line would not be linear. Some looked for reasons why the student’s statement was correct, such as a systematic error in the data.

- (b) The student drew a graph of how current varies with p.d. She drew a straight line on the graph and claimed that the data demonstrates that the filament lamp obeys Ohm’s law because the graph is linear.



Assess the validity of the student’s statement.

(4)

Ohm's law states that current and voltage are directly proportional. This graph only shows that they are proportional, by the linear line. It doesn't show direct proportionality as it doesn't pass through the origin. Therefore it only somewhat fulfills Ohm's law.



This response makes a correct statement of Ohm's law and identifies that the line drawn does not pass through the origin. However, there is some confusion in the statement of the conclusion as it is thought that the graph shows a "proportional" but not a "directly proportional" relationship. The idea that a straight line shows a proportional relationship and a straight line through the origin shows a directly proportional relationship is a common misconception seen in a number of responses.



If there is a (directly) proportional relationship between two quantities, then a straight line that passes through the origin will be obtained when a graph of the two quantities is drawn.

Assess the validity of the student's statement.

(4)

The statement is invalid. Ohm's law states that current and voltage are directly proportional, this means the graph would have to pass through the origin with a straight line. This graph does not go through 0. Furthermore, the shape of the graph is in fact ~~linear~~ ^{curved}, showing that it is not proportional. If more readings were taken between 0V and 3V the curve would be more noticeable.



This is a good response scoring all 4 marks.



Remember that not all mean lines are straight. Sometimes data indicates a curve rather than scatter about a straight line.

Question 4 (c)

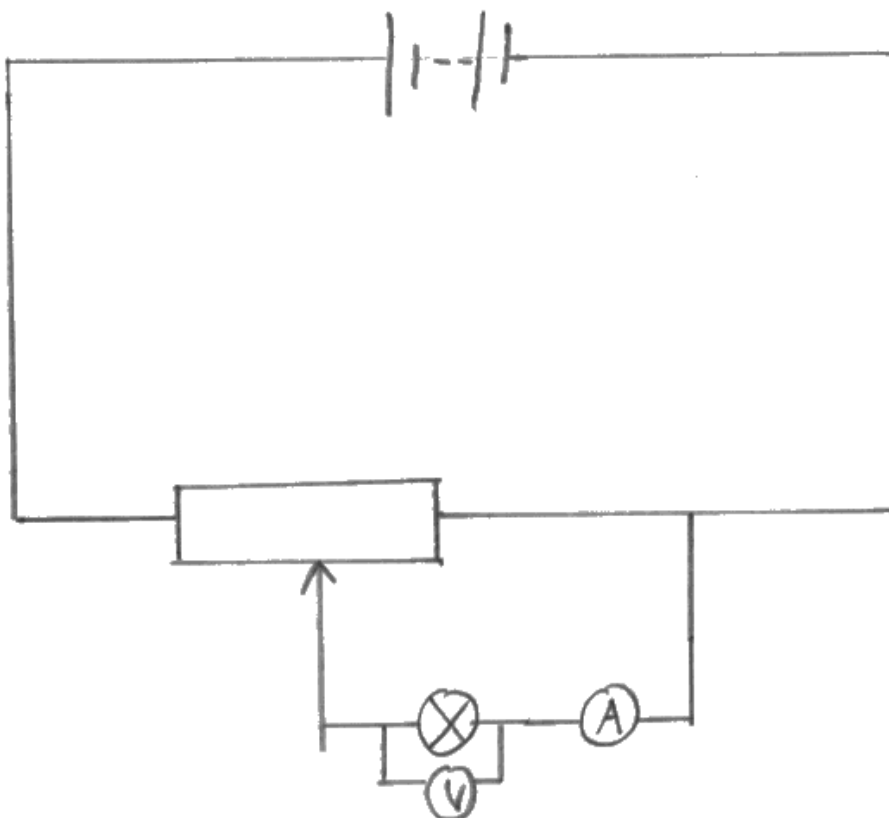
This question required students to be familiar with the potential divider circuit. It is clear from the range of responses seen that most students had little idea how to draw a potential divider circuit. This may be due to insufficient practical experience of such circuits.

Many answers were copies of the original circuit with the components arranged in a slightly different order. Many students thought a rheostat controlling the current in the circuit would also act as a potential divider. The ammeter was often moved closer to the battery and some students simply replaced the battery with a variable power supply.

(c) Using the circuit shown the student was unable to obtain data for p.d.s less than 2.5 V.

Draw a diagram of a circuit the student could have used to enable a full range of p.d.s from 0 to 12 V to be investigated.

(2)

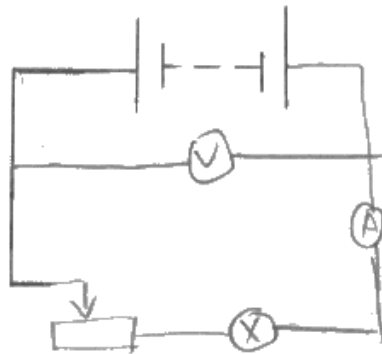


The circuit drawn is correct and scores both marks.

(c) Using the circuit shown the student was unable to obtain data for p.d.s less than 2.5 V.

Draw a diagram of a circuit the student could have used to enable a full range of p.d.s from 0 to 12 V to be investigated.

(2)



At first glance this circuit looks like a potential divided circuit. However, it is just another way of indicating that there is a variable resistor in the circuit. Also note that the voltmeter is not measuring the potential difference across the lamp.

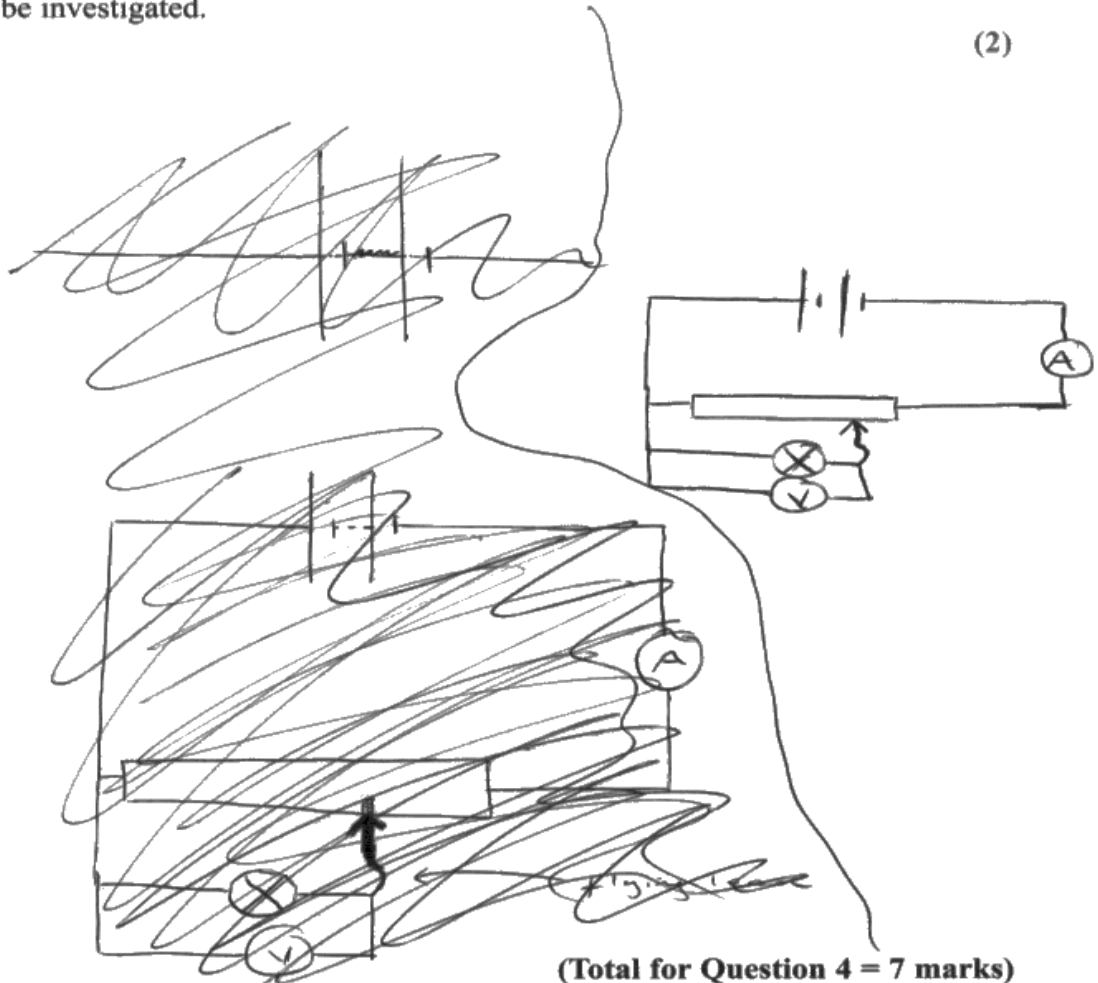


Voltmeters are connected in parallel with the component **across** which they are measuring the p.d.

(c) Using the circuit shown the student was unable to obtain data for p.d.s less than 2.5 V.

Draw a diagram of a circuit the student could have used to enable a full range of p.d.s from 0 to 12 V to be investigated.

(2)



The circuit includes a potential divider, but the ammeter is not measuring the current through the lamp.



Ammeters are connected in series with the component **through** which they are measuring the current.

Question 5 (a)

In part (i) the majority of answers identified the outlier, which was 87.5 cm, and correctly calculated a more accurate value for the mean length. Some students re-did the calculation giving their answer to a greater number of significant figures. In part (ii), the calculation of the time period using the more accurate value was usually carried out correctly. The most frequent mistake was to forget to convert the mean length in cm to a length in m, which resulted in a value for T which was out by a factor of 10.

5 A student is using a simple pendulum to determine a value for the acceleration of free fall g .



(a) She measures the length l of the pendulum four times with a metre rule and records the following values.

l / cm			
l_1	l_2	l_3	l_4
85.5	86.0	87.5	85.5

She calculates the mean length l_m of the pendulum using the following method:

$$l_m = \frac{85.5 + 86.0 + 87.5 + 85.5}{4} = 86.1 \text{ cm}$$

(i) Calculate a more accurate value for l_m .

(2)

$$\frac{85.5 + 86.0 + 85.5}{3} = 85.67$$

$$l_m = 85.67 \text{ cm}$$

(ii) Determine the time period of the oscillations of this pendulum, using your calculated value for l_m .

(2)

$$T = 2\pi \sqrt{\frac{l}{g}} \quad 2\pi \times \sqrt{\frac{85.67}{9.81}} = 18.57$$

$$\text{Time period of oscillations} = 18.57 \text{ s}$$



In part (i) the outlier has been excluded from the calculation of the mean length, but the final answer is given to too many significant figures. In part (ii) the length in cm has been substituted into the expression for time period.



Ensure that all quantities are expressed in SI units before substituting them into an equation.

(i) Calculate a more accurate value for l_m .

(2)

$$\frac{85.5 + 86.0 + 87.5 + 85.5}{4} = 86.125$$

$$0.86125 \text{ m}$$

$$86.125 \text{ cm}$$

$$\textcircled{0.86125 \text{ m}}$$

$$86.125 \text{ cm}$$

$$l_m =$$

(ii) Determine the time period of the oscillations of this pendulum, using your calculated value for l_m .

(2)

$$T = 2\pi \sqrt{\frac{L}{g}} \quad 2\pi \sqrt{\frac{0.86125}{9.81}} =$$

$$1.8617 \text{ seconds}$$

$$\text{Time period of oscillations} = 1.8617 \text{ seconds}$$



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Examiner Comments

In part (i) the outlier has been included in the calculation of the mean length, and the final answer is given to a greater number of significant figures than in the question. In part (ii) the length in m has been substituted into the expression for time period. Once again the final answer is given to too many significant figures.



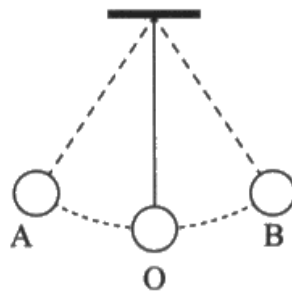
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Examiner Tip

The number of significant figures in your final answer should reflect the number of significant figures in your raw data.

Question 5 (b)

Using an increased number of oscillations was the most common response, although students who gave this as a response sometimes omitted to give a reason why this modification should be made. Fiducial markers were often suggested, but usually placed at A rather than O. Very few students suggested letting the pendulum settle before starting to time. Suggestions of a larger amplitude or a longer length for the pendulum were more common than might have been expected. Many students made glib references to the use of a data logger or a video camera assuming that these would automatically lead to improved values for T .

- (b) She sets the pendulum into oscillations with small amplitude and uses a stopwatch to determine the time period.



The student releases the pendulum at A and simultaneously starts the stopwatch. She measures the time taken for 5 oscillations and divides the value by 5. She repeats the procedure twice and calculates a mean time period.

Explain two modifications to the student's method that would improve the value obtained for the time period.

(4)

use data logger instead of stopwatch (remove human error + reaction speed)

have set time instead of using amount of oscillations.



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Examiner Comments

It's not clear how the use of a data logger would improve the value obtained for T . The idea that the student should count a number of oscillations that occur in a set time was seen in a number of responses, although this would lead to a less accurate value for T .

Instead of 5 oscillations, use 10-20 this will reduce % error because roughly the same absolute error is being divided by 10-20 not 5.

Set a back board up behind it ~~and~~ with markers for release points this will make it easier to keep release point the same and will help to make it easier to stop timer at peak displacement.

(Alternatively use this back board with a camera and count frames for 10-20 oscillations then calculate time from ^{that})

(Total for Question 5 = 8 marks)



This response scores 2 marks for the idea of increasing the number of oscillations to reduce the percentage uncertainty. However there isn't enough detail given in the other suggestion for any further credit to be given.

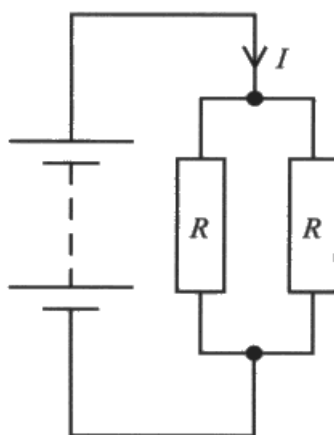
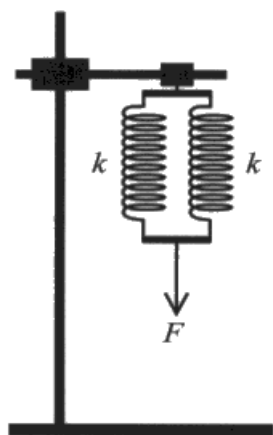
Question 6 (a)

The specification gives a number of standard derivations that students should be familiar with. It was encouraging to see that the vast majority of students were well prepared to answer this question.

Most students made a creditable attempt at answering this question, usually with the desired outcome. Some students carried out some complicated algebra, which was in fact correct, to get to the right answer. Some students did not make explicit reference to $l = l_1 + l_2$, and a common mistake for those using the correct method was omit to state that the p.d. values were the same. A significant minority of students referred to identical resistors, which wasn't what was required. A number just quoted the final formula, sometimes using this to show the combined reciprocal formula for R_{eff} .

- 6 A student is experimenting with different combinations of springs and recalls that in physics it is often possible to model different physical situations in similar ways.

The student suggests that a parallel combination of springs could be a model for a parallel combination of resistors in a circuit.



perfect

- (a) Derive an expression for the effective resistance R_{eff} of two resistors R_1 and R_2 connected in parallel in a circuit.

Parallel

~~Parallel~~ $\rightarrow \frac{1}{R} + \frac{1}{R} = \frac{2}{R} \therefore \frac{R}{2}$

(3)

$R_{\text{eff}} = \frac{R}{2}$

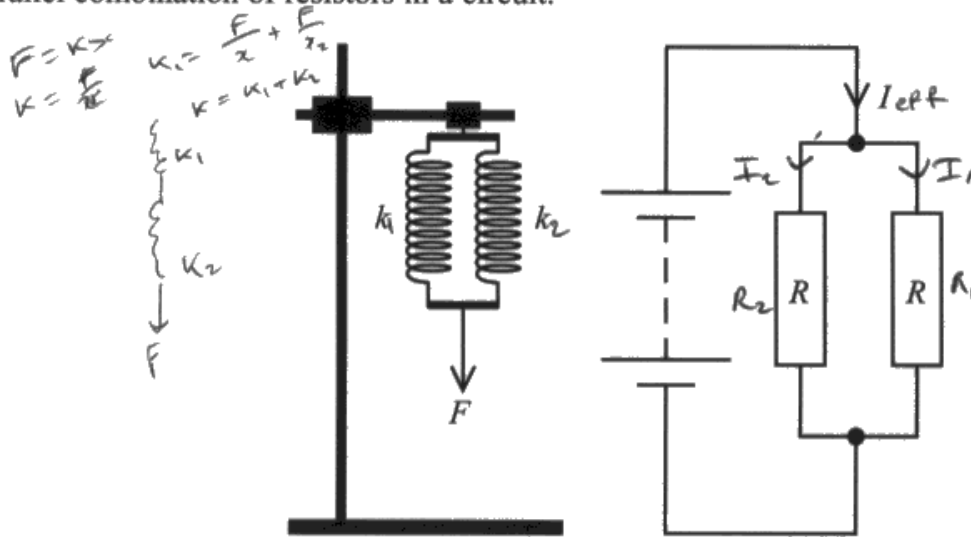


ResultsPlus
Examiner Comments

This response assumes that the two resistors have the same resistance. It gives just enough detail for 1 mark to be awarded.

- 6 A student is experimenting with different combinations of springs and recalls that in physics it is often possible to model different physical situations in similar ways.

The student suggests that a parallel combination of springs could be a model for a parallel combination of resistors in a circuit.



- (a) Derive an expression for the effective resistance R_{eff} of two resistors R_1 and R_2 connected in parallel in a circuit.

(3)

In parallel, voltage is same and current splits.

$$I_{\text{eff}} = I_1 + I_2$$

$$I = \frac{V}{R}$$

$$\therefore \frac{V_{\text{eff}}}{R_{\text{eff}}} = \frac{V}{R_1} + \frac{V}{R_2} \quad \text{as } V \text{ is the same,}$$

$$\frac{1}{R_{\text{eff}}} = \frac{1}{R_1} + \frac{1}{R_2} \Rightarrow R_{\text{eff}} = \frac{R_1 R_2}{R_1 + R_2}$$



This response scores all 3 marks.

Question 6 (b)

This question was set in a novel context and on the whole it was poorly answered. Those students who dealt reasonably well with the context often omitted to give enough detail in their responses.

A significant number of students were able to earn 3 marks for stating that the spring constant was double that of a single spring, the total resistance was half and that the suggestion was invalid. Answers that provided more detail usually mentioned the force sharing but not that the extension would be half. The equation for resistance quoted was often the general equation from (a) rather than the equation for equal resistances, which was the one required. Maybe some students were over focused on stating the conclusion, rather than developing the physics that led to the conclusion.

(b) Assess the validity of the student's suggestion by considering the effective stiffness of two identical springs in parallel.

(6)

When springs are connected in parallel their total value of stiffness is calculated by $k_T = k_1 + k_2$ therefore the students suggestion is not valid as the total stiffness of two identical springs will equal $2k$ whilst for two identical resistors the total resistance will be $R/2$. This therefore shows that parallel comparison of springs is not a suitable model for a parallel combination of resistors making the students statement invalid.



ResultsPlus
Examiner Comments

This response is typical. The two situations are being compared correctly, but there isn't enough detail in the response for more than 3 marks to be awarded.



In questions that ask you to assess the validity of something, be sure to include sufficient detail of the physics theory that allows you to make your assessment.

(b) Assess the validity of the student's suggestion by considering the effective stiffness of two identical springs in parallel.

(6)
When Springs are Combined in Series their Stiffness doubles. ∴ The Stiffness of the System = $2K$. For R the total resistance is reduced. Whereas due to $R_T = \left(\frac{1}{R_1} + \frac{1}{R_2}\right)^{-1}$. The total resistance is half of that of R (presuming they have equal values for resistance). ∴ The effective resistance of the system is $\frac{1}{2} R$ whereas this ~~is~~ in the Spring System the Stiffness is $2K$. Therefore this is an ~~invalid~~ ~~incorrect~~ model as they do not follow the same ~~rule~~ linear rule. They have different gradients.

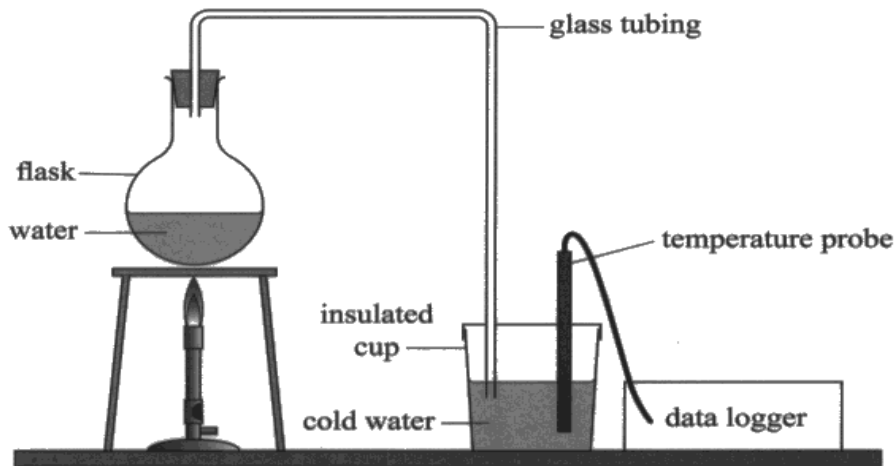


In this response there is some detail given relating to the effective resistance of a parallel resistor combination, although no detail explaining why the effective spring constant of the parallel spring combination should double.

Question 7 (a)

The vast majority of students were able to use the equations $mc\Delta\theta$ and mL , but the key error was to forget to include all of the heat transfers. It was usual for the energy transfer as the condensed steam cooled to be omitted from the calculation. Some students needlessly converted the temperatures from celsius into kelvin.

- 7 A student carried out an experiment to determine the specific latent heat of vaporisation of water using the apparatus shown.



The water in the flask was heated and steam was forced out of the flask and through the glass tubing into the cold water in the insulated cup. The steam condensed as it passed into the cold water.

- (a) The initial temperature of the cold water was 18.5°C and the mass of water in the cup was 255.0 g . After steam had been passed through the water for some time the temperature had risen to 26.0°C and the mass of the water in the cup was 258.3 g .

Calculate the specific latent heat of vaporisation of water.

(3)

specific heat capacity of water = $4190\text{ J kg}^{-1}\text{ K}^{-1}$

Handwritten: mass of steam condensed = $3.3\text{ g} = 3.3 \times 10^{-3}\text{ kg}$

Handwritten: energy lost by heating water = energy lost by steam + energy lost by steam cooling

$$mc(\theta_2 - \theta_1) = mL + mc(\theta_2 - 100)$$

Handwritten: energy lost by steam condensing = energy gained by water + energy lost by steam cooling

$$0.255 \times 4190 \times (26 - 18.5) = 3.3 \times 10^{-3} \times L + 0.0033 \times 4190 \times (26 - 100)$$

$$\rightarrow L = 2118235\text{ J kg}^{-1}$$

Specific latent heat of vaporisation of water = 2.12 MJ kg^{-1}



ResultsPlus
Examiner Comments

This response scores all 3 marks.

Steam at 100°C . Energy transferred to water from steam:

$$E = mc\Delta T = 0.255 \text{ kg} \times 4190 \times (26 - 18.5) = 8013 \text{ J}$$

$$\text{Mass of steam} = 258.3 - 255 = 3.3 \text{ g.}$$

newly condensed

$$\text{Energy lost by water cooling} = 0.0033 \times 4190 \times (100 - 26) = 1023 \text{ J}$$

$$\text{Difference in energies} = 8013 \text{ J} - 1023 \text{ J} = 6990 \text{ J} \text{ must}$$

have come from latent heat. $E = L\Delta m \Rightarrow L = \frac{E}{\Delta m}$

$$L = \frac{6990}{0.0033} = 2.12 \times 10^6 \text{ J kg}^{-1}$$

$$\text{Specific latent heat of vaporisation of water} = 2.12 \times 10^6 \text{ J kg}^{-1}$$



ResultsPlus
Examiner Comments

This response scores all 3 marks.



ResultsPlus
Examiner Tip

Begin by writing a word equation for the energy transfers involved as the steam condenses and then cools down.

Question 7 (b)

From the responses seen it was clear that many students could not visualise this experiment, and so they struggled to understand aspects of the method. Many students fell back on GCSE answers like 'use a stirrer' or made vague statements such as 'energy is lost'.

In part (i) few students realised that the reason for leaving the water boiling for a few minutes was to bring the tubing up to temperature, so that steam didn't condense in the tubing. Most students wrote about making sure all the water reaches boiling point, or to give enough time for all the water turn into steam. Some students thought that time was needed to break the bonds in the water molecules, or for the steam to gains enough kinetic energy to move to the cup. In part (ii) many students identified the source of error as energy transfer to the surroundings but many failed to say, 'from the tube'. Also, many students mentioned insulating the flask or the cup (already insulated) rather than insulating the tube. Many correctly said that the tubing should be insulated or shortened, but were often less precise in describing the reason for this.

(b) (i) Explain why the water was heated to boiling point and left boiling for a few minutes before the insulated cup of cold water was put in place.

(2)

It was left boiling for a few minutes so all the air could pass out of the glass tubing so only steam would come out, ensuring the accuracy of the experiment

(ii) Identify a significant source of error in this experiment and the steps that should be taken to minimise its effect on the calculated value of the specific latent heat of vaporisation of water.

(2)

The temperature rise of the cold water could be incorrect if convection currents form in the insulated cup so the water should be stirred to reduce this. In addition, some thermal energy from the ~~water~~^{steam} may also be transferred to the surroundings through the glass tubing so it should be insulated instead, i.e. use rubber tubing in order to minimise its effect on the value of L .

(Total for Question 7 = 7 marks)



Expelling air from the tubing is a good idea, but for this we would not need to keep the water boiling for a few minutes before putting the cup in place. In part (ii) there is a reference to stirring, which is ignored. However, there is a good description of unwanted energy transfer and lagging for 2 marks.

Question 8 (a)

Most students were able to calculate the magnification. A number of students thought that they should use the area of the object and that of the image on the screen. In weaker responses they substituted the image and object height into the lens formula. Some chose to substitute for u rather than v and failed to find v through the magnification or a second use of the lens formula. The manipulation of the lens formula also proved beyond some students. Quite a few students used the $u \approx f$ method successfully.

8 A converging lens can be used to produce a real image on a screen.

- (a) A converging lens of focal length 15.0 cm is used to project an image of an illuminated object onto a screen. The object is a circle of diameter 4.0 mm and the image must be as large as possible on a screen of size 0.75 m by 1.25 m.

Calculate the distance between the lens and the screen for this image to be displayed.

(3)

$$4 \text{ mm} = 0.004 \text{ m}$$

$$\frac{0.75}{0.004} = 187.5 \text{ magnification}$$

$$\frac{v}{u} = 187.5 \quad \frac{1}{15} = \frac{1}{v} + \frac{1}{u}$$

$$\frac{1}{15} - \frac{1}{75} = \frac{1}{u}$$

$$\frac{1}{u} = \frac{4}{75} \quad u = 18.75$$
$$18.75 - 15 = 3.75$$

Distance between lens and screen = 3.8 cm



ResultsPlus
Examiner Comments

The magnification is calculated correctly, so MP1 can be awarded. However, the lens equation is used incorrectly, and so no further credit can be given.

8 A converging lens can be used to produce a real image on a screen.

- (a) A converging lens of focal length 15.0 cm is used to project an image of an illuminated object onto a screen. The object is a circle of diameter 4.0 mm and the image must be as large as possible on a screen of size 0.75 m by 1.25 m.

Calculate the distance between the lens and the screen for this image to be displayed.

$$v = ? \quad (3)$$

$$\text{image size} = 0.75 \text{ m}$$

$$\text{object size} = 4 \times 10^{-3}$$

$$\text{magnification} = 187.5$$

$$\frac{v}{u} = 187.5$$

$$u = \frac{v}{187.5}$$

$$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$$

$$\frac{1}{v/187.5} + \frac{1}{v} = \frac{1}{0.15}$$

$$\frac{187.5 + 1}{v} = \frac{1}{0.15}$$

$$0.15 \times 188.5 = v$$

$$v = 28.275 \text{ m}$$

Distance between lens and screen = 28 m



ResultsPlus
Examiner Comments

This solution scores all 3 marks.

Question 8 (b)

Many gave an expression for the inverse square relationship but did not define terms. The second marking point was commonly awarded, with only a few students forgetting to make a statement about validity. Those students who took the second route, considering power over an area, were likely to score both marks. Some students failed to identify that the intensity or brightness of the image would fall to one quarter of the original brightness. Some stated that it would fall by one quarter, and some reasoned in support of the magazine statement that it would be one half of the original brightness.

(b) A magazine article includes the statement:

If the distance from the lens to the screen is doubled, the brightness of the image is halved.

$$I = \frac{P}{A}$$

Assess the validity of this statement.

(2)

If the lens to distance to the screen is doubled according to the ~~inverse~~^{inverse} square law it will cover 4 times the area it did before this will mean that the brightness of the image is actually a quarter of it initial and it is not halved.



ResultsPlus
Examiner Comments

In this response the idea that the area is quadrupled and so the brightness falls to one quarter is correctly stated. However, the use of "it" in "according to the inverse square law it will cover 4 times the area" leaves it unclear whether it is the power that is being spread over this area.

(b) A magazine article includes the statement:

If the distance from the lens to the screen is doubled, the brightness of the image is halved.

Assess the validity of this statement.

(2)

$$I = \frac{P}{A}$$

$$I = \frac{P}{4\pi d^2}$$

$$\frac{P}{4\pi(2d)^2} = \frac{P}{16\pi d^2} = \frac{I}{4}$$

Therefore, if the distance from the lens to the screen is doubled, the brightness is quartered.



ResultsPlus
Examiner Comments

An explanation based on equations, but little indication of what the quantities being referred to are.



ResultsPlus
Examiner Tip

If you are using an equation as part of a description or explanation, always define the meaning of the symbols (unless these are already given in the question).

Question 9 (a)

This question asked students to discuss an explanation of the photoelectric effect produced by a student. A description of the photoelectric effect without reference to the explanation given in the stem was not an answer to the question and so did not score full marks.

This question should have been straightforward, but it was relatively poorly answered. The majority of answers correctly said that there was a threshold frequency and one photon was absorbed by one electron. Most went on to say that the energy needed to release electrons was called the work function or, alternatively, that photon energy above the work function would release electrons. However, many students did not make explicit reference to the work function. Few students stated that photons had an energy given by hf .

9 A student has been learning about the photoelectric effect.

(a) The student was asked by his teacher to explain the photoelectric effect. He gave the following explanation:

	Light above a certain threshold is able to free electrons from a metal, because the light gives energy to electrons in the metal.
	Some of this energy is used to release the electrons from the metal and the rest becomes kinetic energy of the freed electron.

Discuss whether the student's answer fully explains the photoelectric effect.

(4)

- a photon is a discrete packet of energy in form of electromagnetic radiation
 - 1 photon is absorbed by 1 electron
 - the teacher is correct in saying that there is a minimum ~~frequency~~ threshold frequency for the ~~electron to free~~ photon to have enough energy to free an electron, to overcome the ~~the~~ work function ϕ
 - the teacher never stated that light acts as a particle in this effect
 - photon energy is given by $E = hf$ so energy of a photon is ~~is~~ directly proportional to its frequency.
- ~~the~~ $hf = \phi + \frac{1}{2}mv^2$ where $\frac{1}{2}mv^2$ is the kinetic energy of the electron released and ϕ is the energy required of the photon to free the electron as the teacher stated

This is a good response, scoring all 4 marks.

9 A student has been learning about the photoelectric effect.

(a) The student was asked by his teacher to explain the photoelectric effect. He gave the following explanation:

Light above a certain threshold is able to free electrons from a metal, because the light gives energy to electrons in the metal. Some of this energy is used to release the electrons from the metal and the rest becomes kinetic energy of the freed electron.

Discuss whether the student's answer fully explains the photoelectric effect.

(4)

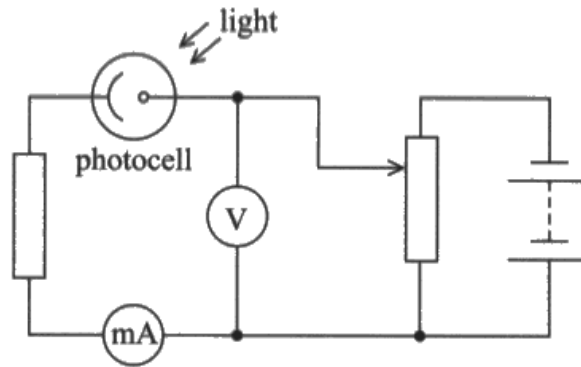
It does not fully explain the photoelectric effect. The light must be above the ~~threshold~~ work function of the metal ~~and~~ and the threshold frequency to free surface electrons from the metal. The energy must match the ~~discrete~~ difference between the discrete energy levels of the ~~an~~ electron for ~~it~~ the electron to move up an energy level and release a photoelectron.

This response is quite confused and lacking in detail. There is a reference to threshold frequency, which is just about enough for MP1, but nothing else. The response seems to indicate that in the photoelectric effect electrons are promoted to higher energy levels by the incident light.

Question 9 (b)

This question was generally well done. The majority of students correctly rearranged the photoelectric equation so that they could compare it with $y = mx + c$. They then said that a graph of stopping potential against frequency could be plotted with a gradient equal to the Planck constant divided by the electron charge. Alternatively a graph of maximum K E, or eV_s , against frequency could be plotted with a gradient equal to the Planck constant. Some students had difficulty rearranging the photoelectric equation and the majority of students who gave a good answer omitted to define Φ as the work function in the photoelectric equation so would not gain full marks.

(b) The student sets up a circuit to investigate the photoelectric effect.



The student illuminates the photocell with light of known frequency f . A current is produced in the circuit due to the emitted electrons. He adjusts the potential difference, using a potential divider, until the reading on the milliammeter is zero and records the corresponding reading V_s on the voltmeter. He repeats this procedure for other frequencies of light.

When the reading on the milliammeter is zero the maximum kinetic energy of the emitted electrons is given by eV_s .

Explain how the student can use his results to determine a value for the Planck constant h using a graphical method.

$$E = \phi + \frac{1}{2} m v_{max}^2 \quad \frac{1}{2} m v_{max}^2 = e V_s \quad (5)$$

$$E = \phi + e V_s \quad E = hf$$

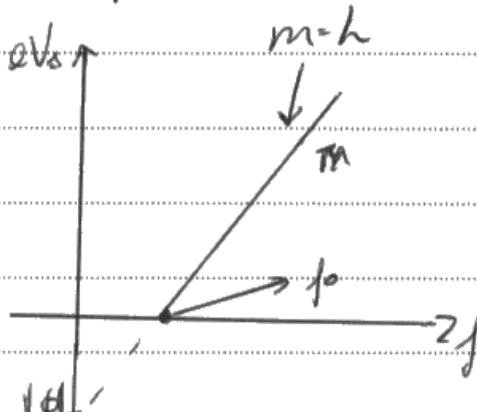
$$hf = \phi + e V_s$$

$$hf - \phi = e V_s$$

After getting the values
 plot a graph of $e V_s$ (k.E max) against
 f (freq.). The gradient
 produced is Planck's constant

$$e V_s = hf - \phi$$

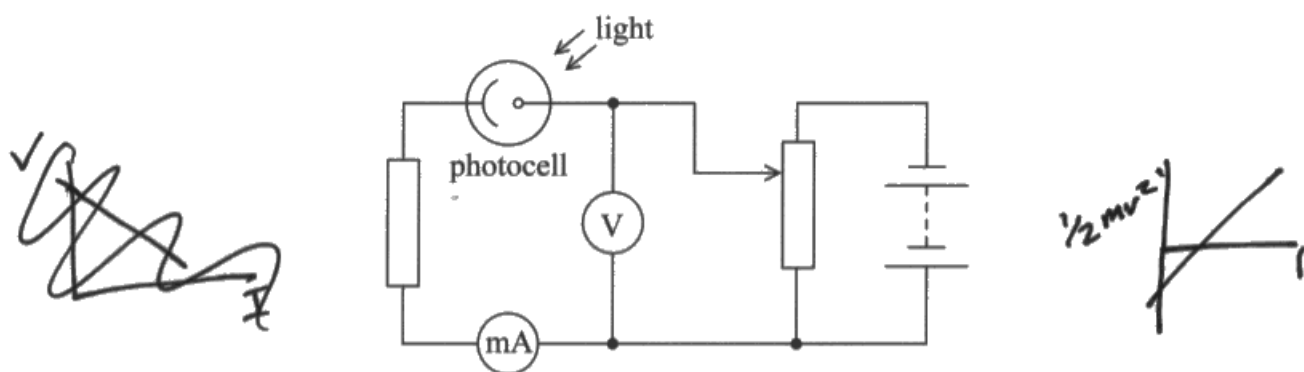
$$y = mx + c$$





This is a good response, which gains all but the first MP. The approach is quite algebraic, but there is enough detail given to understand what the equations mean.

(b) The student sets up a circuit to investigate the photoelectric effect.



The student illuminates the photocell with light of known frequency f . A current is produced in the circuit due to the emitted electrons. He adjusts the potential difference, using a potential divider, until the reading on the milliammeter is zero and records the corresponding reading V_s on the voltmeter. He repeats this procedure for other frequencies of light.

$$hf = \phi + \frac{1}{2}mv^2$$

When the reading on the milliammeter is zero the maximum kinetic energy of the emitted electrons is given by eV_s .

$$hf = \phi + V_s e$$

Explain how the student can use his results to determine a value for the Planck constant h using a graphical method.

(5)

The student can record in a table the frequency of light used and the stopping voltage for each frequency. Collect the values for voltage and frequency for at least 6 different frequencies of light. Then multiply each value of stopping voltage by the charge of an electron (1.6×10^{-19}). This will give the maximum kinetic energy of the electrons for each frequency.

Plot a graph with frequency on the x-axis and $E_{k \max}$ on the y-axis. This gives the equation $E_{k \max} = hf - \phi$. To find the value of Planck's constant, find the gradient of the straight line graph.



This response includes an introductory section on the data collection, which isn't required by the question. However, the detail given following this section is enough for all but the first MP.

Question 9 (c)

Although many students scored full marks on this question, some used this as an opportunity to discuss wave-particle duality, which wasn't what was being asked. Photons were often mentioned without specifying that these were the particles of light. Few students referred to the evidence of photons having momentum in their answers.

(c) This experiment demonstrates the particle nature of light.

Explain what is meant by the particle nature of light.

(2)

- The theory that light behaves as a particle, opposed to the wave nature of light.
- ~~The~~ The behaviour of light is in accordance with the behaviour of a particle.



ResultsPlus
Examiner Comments

This response gives little information other than a reference to wave-particle duality, and so it did not score any marks.



ResultsPlus
Examiner Tip

Read the question carefully and make sure that your response is an answer to the question being asked.

(c) This experiment demonstrates the particle nature of light.

Explain what is meant by the particle nature of light.

(2)

- light behaves as particles with a fixed quanta/amount of energy known as photons
- It undergoes phenomena only observed by particles and not waves



This response says enough for both marks to be awarded.

Question 10 (a)

The vast majority of students obtained a correct answer to part (i), but some used the wrong equation of motion in part (ii), or sometimes the wrong distance. In weaker responses the total distance was divided by the total time.

- 10 The Shanghai Maglev Train is the first commercially operated high-speed magnetic levitation train in the world, connecting the airport and central Shanghai.



- (a) The total distance travelled is 29.9 km and the total journey time is 440 s. The train starts from rest and reaches a speed of 97 m s^{-1} in 120 s.

- (i) Calculate the average acceleration of the train during the first 120 s.

(2)

$$s = ut + \frac{1}{2}at^2$$

$$v = u + at$$

$$\therefore a = \frac{v}{t}$$

$$\therefore a = \frac{v}{t} = \frac{97}{120} = 0.81 \text{ m s}^{-2}$$

$$\text{Average acceleration of train} = 0.81 \text{ m s}^{-2}$$

- (ii) Calculate the average speed of the train for the period following the 120 s acceleration.

(3)

$$s = ut + \frac{1}{2}at^2 = \frac{1}{2}(0.81)(120)^2 = 5832 \text{ m}$$

$$\therefore s_{\text{after acceleration}} = 29.9 \times 10^3 - 5832 = 24,068 \text{ m}$$

$$t_{\text{after acceleration}} = 440 \text{ s} - 120 \text{ s} = 320 \text{ s}$$

$$\therefore v = \frac{s}{t} = \frac{24068}{320} = 75 \text{ m s}^{-1}$$

$$\text{Average speed of train} = 75 \text{ m s}^{-1}$$



ResultsPlus
Examiner Comments

This response scored full marks.

(i) Calculate the average acceleration of the train during the first 120 s.

(2)

~~$s = 29.9 \times 10^3$~~
 $s = 29.9 \times 10^3$
 $u = 0$
 $v = 9.7$
 $a = a$
 $t = 120$

$$v = u + at$$
$$a = \frac{v - u}{t} = \frac{9.7}{120} = 0.81 \text{ ms}^{-1}$$

Average acceleration of train = 0.81 ms^{-1}

(ii) Calculate the average speed of the train for the period following the 120 s acceleration.

(3)

$s = s$
 $u = 9.7$
 $v = 9.7$
 $a = 0.81$
 $t = 120$

$$v^2 = u^2 + 2as$$
$$s = \frac{(9.7)^2}{2(0.81)} = 5808 \text{ m}$$
$$s = \frac{29.9 \times 10^3}{2} - 5808 = 24092 \text{ m}$$
$$\frac{s}{t} = \frac{24092}{440.120} = 75.3 \text{ ms}^{-1}$$

Average speed of train = 75.3 ms^{-1}



ResultsPlus
Examiner Comments

This response would have scored full marks, but MP2 in part (i) could not be awarded as there is a unit error.



ResultsPlus
Examiner Tip

Always check the units of your final answer.

Question 10 (b)

Most answers scored the first mark. Some students referred to “drag” rather than frictional force, although those doing so usually qualified it with a mention of the tracks. A significant number of answers referred to greater acceleration or higher speed but did not relate this to the maximum speed and as a result gained no credit. References to energy being “lost” rather than transferred or wasted were relatively common.

(b) Electromagnetic forces enable the train to levitate above a steel rail.

Explain why magnetic levitation is an advantage for a high-speed transport system.

(2)
This is because there ^{is} much less frictional drag, enabling the train to go at very high speeds a lot more easily than on tracks.



This response refers to “frictional drag”, and it is unclear whether this means less resistive forces due to no contact with the rails or less air resistance, so MP1 was not awarded. The phrase “go at very high speeds a lot more easily” was not thought to be sufficient for MP2.



Be sure to use technical terms accurately.

(b) Electromagnetic forces enable the train to levitate above a steel rail.

Explain why magnetic levitation is an advantage for a high-speed transport system.

(2)
It will prevent friction between the tracks and the train. This means that there will be no energy loss and all the energy put in will move the train. This will increase the speed. $E_k = \frac{1}{2}mv^2$.



ResultsPlus
Examiner Comments

This is a good description of reduced friction, so MP1 is awarded. The stated consequence of reduced friction (no energy loss) is just enough for MP2.

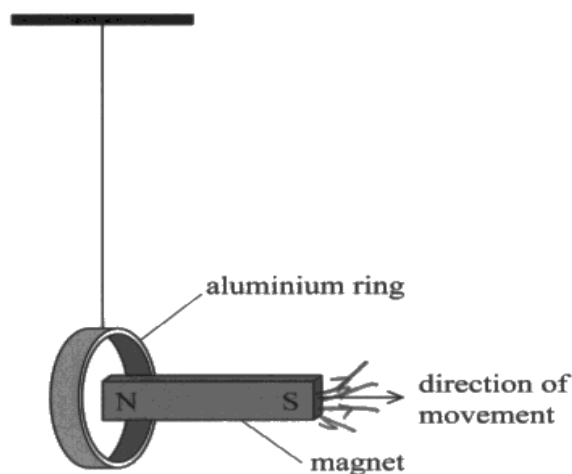
Question 10 (c)

This question is an extended writing question which assesses the candidates' ability to show a coherent and logical structured answer with linkage and fully sustained reasoning. There are 6 indicative content points, for which a maximum of 4 marks can be awarded. There are two further marks available for appropriate linkage of ideas.

Although there are many examples of model answers to the first part of this question, as the physics theory has been examined many times in the previous specification, students found it difficult to apply the theory to the particular context given. Most responses seen included a change in flux, and an induced e.m.f., but other steps were often missed out before the explanation concluded with a reference to the change being opposed and a force being produced. Some students just discussed Faraday's laws and did not relate these to the situation in the question.

***(c) A linear induction motor provides the force to accelerate the train forwards. A current flows in sequence through coils of wire mounted in the track. The train is dragged along as the magnetic field progresses along the coils of wire in the track. This is similar to moving a permanent magnetic field away from a conductor.**

A teacher demonstrates this effect by quickly removing one end of a bar magnet from a suspended aluminium ring.



When the magnet is removed from the ring, the ring moves in the same direction as the magnet.

Explain, using the laws of electromagnetic induction, why the ring moves in the direction of the magnet.

(6)

When the north end of the bar magnet is moved quickly through the ring, it induces an e.m.f. in the ring. This induces a current and a magnetic field in the ring. Due to Lenz's law, the direction of the force of the magnetic field of the ring opposes that that moved it (North side of the bar). Therefore, it moves in the direction of the South pole of the magnet, which is the direction the magnet is moving.



This response omits any reference to changes in flux linkage, although indicative content points 2 through to 5 are included. 4 indicative content points gives a mark of 3 for content. The lack of a clear argument (no starting point and no end point) means that no linkage marks are justified, and so this response scores 3 marks.



Plan your answer to a question like this before you start to write. Planning your response will help you to write your answer out logically and with a minimum of repetition.

- The movement of the magnet causes a changing magnetic flux which induces an emf in the ring
- The induced emf causes a current in the ring producing its own magnetic field
- The two magnetic fields will oppose each other due to Lenz's law
- This means the ring is attracted to the magnet
- As the magnet keeps moving the attraction causes the ring to follow it



ResultsPlus
Examiner Comments

This is a good answer to the question. All 6 indicative content points are made, giving a mark of 4 for content. The logical flow of the argument is good enough for both linkage marks to be given.

Question 11 (a)

This item was very poorly answered with the vast majority of students scoring zero. Responses indicated that it was a common misconception held by students that a satellite in orbit about the Earth is so far away from the centre of the Earth that the gravitational field strength can be assumed to be zero. Many students who thought that g was zero even argued this by using inverse square law. The most common mark earned was for a reference to free fall, but those who scored on MP1 often didn't then get MP2. There were occasional references to centripetal forces for MP2, though the necessary qualifier, "all of the weight", was rarely seen.

- 11** The International Space Station (ISS) is in a low Earth orbit. Astronauts in ISS have an apparent weight of zero. In order to determine their mass, the astronauts must secure themselves to a platform which is set into oscillation and moves with simple harmonic motion.



- (a) Explain why the astronauts in the ISS have an apparent weight of zero.

(2)

they are in constant free-fall towards ~~the~~ Earth, due to being in orbit. This means ~~they are in~~ ~~the~~ constant ~~state~~ ~~with~~ the ~~ground~~ is 0.



Both marking points are seen here, so full marks for this response.

Question 11 (b)

Most students have an idea what simple harmonic motion is. However, although many students seem well trained on this question, many failed to score full marks. This was generally due to missing words in their statement, such as not specifying the point that displacement is measured from. A small number of students stated that displacement is measured from equilibrium. In a formal statement of simple harmonic motion they should be clear that they are measuring displacement from a point or position. Some students used an equation, but did not define the terms.

(b) State what is meant by simple harmonic motion.

(2)

* The restoring force is proportional to displacement from the equilibrium position

* Always acting towards the equilibrium position [i.e. in opposite direction to displacement.]



ResultsPlus
Examiner Comments

Both marking points are seen here, so full marks for this response.



ResultsPlus
Examiner Tip

Learn standard definitions so that your answers to questions like this are accurate and complete.

(b) State what is meant by simple harmonic motion.

(2)

Acceleration is directly proportional to displacement, in the opposite direction. Acceleration always acts towards the equilibrium position.

$$a \propto -x$$



ResultsPlus
Examiner Comments

In this response the displacement is not specified as being from the equilibrium position, so MP1 is not awarded. The response then continues with an ambiguous statement "in the opposite direction". It's not clear what it's in the opposite direction to. However, the response then goes on to specify that acceleration always acts towards the equilibrium position, and so MP2 can be awarded.

Question 11 (c)

Part (i) was usually well answered with students saying that a large number of oscillations (greater than 5) was timed to determine the time period and hence the frequency. Part (ii) was not usually as well answered as part (i). To be correct they had to say that the amplitude was measured and then the maximum speed was determined e.g. by using $v_{\max} = 2\pi f x_{\max}$.

Many used $v = -A\omega \sin \omega t$ in their explanation but did not state $\sin \omega t$ was equal to 1 so were not awarded MP2. Common incorrect answers related to measuring an average speed (total distance over time period), rather than a maximum speed.

(c) Describe how, using a stopwatch and a ruler, the following quantities could be determined for the oscillating platform:

(i) the frequency of oscillation

(2)

The oscillation for oscillations. The time taken for 10 oscillations could be taken with a stopwatch and divided by 10 to calculate the time period. $\frac{1}{\text{time period}}$ is the frequency.

(ii) the maximum speed of the platform.

(2)

Velocity = $\frac{\text{distance}}{\text{time}}$, so a part of the oscillation close to the equilibrium (where the oscillation's velocity is highest), could be timed, and divided by the distance it was measured through.



ResultsPlus
Examiner Comments

Both marks can be awarded for part (i). However in part (ii) the response ignores that this is simple harmonic motion and suggests that we can just calculate the average speed, so no credit for part (ii).

(c) Describe how, using a stopwatch and a ruler, the following quantities could be determined for the oscillating platform:

(i) the frequency of oscillation

(2)

The frequency could be obtained by timing 10 oscillations, dividing the result by 10 to get the time period for 1 oscillation. ~~Use~~ $f = \frac{1}{T}$ use this equation to solve for f using your found value of T .

(ii) the maximum speed of the platform.

(2)

use $\omega = 2\pi f$ to find the angular velocity.
find v_{\max} by substituting known values into $v = -A\omega \sin\omega t$, where A is amplitude and t is time period for one oscillation.



ResultsPlus
Examiner Comments

A good response to part (i), but part (ii) can only be given 1 mark, as it is not clear that in the velocity expression $\sin\omega t = 1$.

(c) Describe how, using a stopwatch and a ruler, the following quantities could be determined for the oscillating platform:

(i) the frequency of oscillation

(2)

10 oscillations can be timed using a stopwatch, divide this value by 10 to obtain the period of 1 oscillation as $f = \frac{1}{T}$, frequency is the ~~reciprocal~~ reciprocal of the time period

(ii) the maximum speed of the platform.

(2)

Measure the amplitude of the oscillations using a metre rule, $v_{\max} = Aw$ where $w = 2\pi f$ use the frequency obtained in i) and multiply by the amplitude to obtain maximum velocity.



ResultsPlus
Examiner Comments

A good response to both parts, and so full marks.

Question 11 (d)

The explanation should include reference to the kinetic energy equation as well as the expression for the maximum velocity. It follows that if x_{\max} is doubled, E_k is quadrupled. However, this was not often seen. Nonetheless, many correctly stated that K.E is quadrupled and so were awarded MP2.

- (d) The platform continues to move with simple harmonic motion at the same frequency, *what T was*
but its amplitude is doubled. *was used*

Explain how the maximum kinetic energy of the platform will change. *prior work*
separated

(2)

*The velocity has doubled as $v = -Aw$ where w is constant
so $v \propto A$ so $v = 2v$, then $ke = \frac{1}{2}mv^2$ plugging in v
 $= 2v$ then $ke = 4 \times$ greater as $2^2 = 4$, than before*



ResultsPlus
Examiner Comments

A good response that gives enough detail for both marks to be awarded.

Question 12 (a)

This question is an extended writing question which assesses the students' ability to show a coherent and logical structured answer with linkage and fully sustained reasoning. There are 6 indicative content points, for which a maximum of 4 marks can be awarded. There are two further marks available for appropriate linkage of ideas.

Although the physics theory has been examined many times in the Legacy specification, students' responses were often lacking in detail. Some students thought that the question was asking for a mathematical derivation of the pressure equation, and so limited the marks that they could be awarded for their response. Many students correctly stated that as the temperature increases the molecular velocity/kinetic energy increases, as does the momentum. Fewer said that the rate or frequency of collision (or even the time between collisions) with the container walls increases as a result. Some students talked about collisions, but did not make a reference to the container walls. This implied that the collisions could have been with each other, which would not have explained an increase of pressure. Some students talked about gas and didn't mention atoms or molecules at all. The idea that the rate of change of momentum is equal to the force was regularly expressed as an equation without the terms being specified. Similarly, pressure as force per unit area was frequently expressed as a formula without defining the terms.

- 12 Our understanding of the atom has developed over time, from early models in which atoms were considered to be hard incompressible spheres, through to the nuclear model of the atom and the ladder model in which electrons exist in a discrete number of allowed energy states.

*(a) The model of atoms as hard incompressible spheres, moving rapidly and randomly, can be used to explain why gases exert a pressure.

Explain, using ideas of momentum, why the pressure exerted by a gas increases as the temperature of the gas increases.

(6)

pat. As temperature increases, ~~the~~ ^{the} gas molecules gain more kinetic energy. As a result, the number of collisions with the wall of the sphere increases as well. The increased kinetic energy of the molecules leads ~~to~~ them to have greater velocities and hence greater momenta. ~~we~~ since $F = \frac{\Delta p}{\Delta t}$ (rate of change of momentum), and since Δp increases and Δt decreases, the resultant force increases. we also know that $P = \frac{F}{A}$, where $P =$ pressure, $F =$ force and A is surface area. Since the surface area is constant and the resultant force increases, we can see that the pressure exerted by the gas increases.



In this response all indicative content points except point 3 are seen, although the clarity of expression is variable. 5 indicative content points equates to a mark of 3 for the content. 2 linkage marks are available, although the clarity of the argument is such that only 1 linkage mark was actually given. Overall this gave a score of 4 marks.



Be specific and use technical terms wherever possible.

12 Our understanding of the atom has developed over time, from early models in which atoms were considered to be hard incompressible spheres, through to the nuclear model of the atom and the ladder model in which electrons exist in a discrete number of allowed energy states.

*(a) The model of atoms as hard incompressible spheres, moving rapidly and randomly, can be used to explain why gases exert a pressure.

Explain, using ideas of momentum, why the pressure exerted by a gas increases as the temperature of the gas increases.

(6)

As the temperature of a gas (in a fixed container of constant volume) increases, then the average kinetic energy per molecule (sphere of gas) increases. This means that the speed at which the molecules are moving inside of the container increases, and hence the rate of collisions of ^{gas}spheres with the sides/walls of the container increases. As the ^{gas}spheres have more kinetic energy, their momentum given by mass \times velocity increases, and hence the momentum transferred to the walls of the container per collision increases (i.e. impulse or Δp of walls increases). If the impulse transferred to the container walls increases, then, as $I \propto \text{Force}$, then the force exerted on the sides and walls of the container ~~is~~ by the molecules of gas increases, as force is the rate of change of momentum, and momentum transfer increases, so F increases. Finally a pressure = $\frac{\text{Force}}{\text{Area}}$ - for a container of fixed volume, Area is constant, and so if the force on the walls increases, then the pressure inside of the container increases. Collisions of gases with walls are elastic, motion of gases is random (Brownian motion) and volume of gases ~~is~~ is negligible (easily compressed)



This is a good answer to the question. All 6 indicative content points are made, giving a mark of 4 for content. The logical flow of the argument is good enough for both linkage marks to be given.



Plan your answer to a question like this before you start to write. Planning your response will help you to write your answer out logically and with a minimum of repetition.

Question 12 (b) (i)

The electric potential equation is new to the current specification, and many students seemed to be unfamiliar with this equation.

Many students tried to use the Coulomb force equation incorrectly. Some students obtained the correct answer by using work done equals force time displacement. This was usually done by making the displacement equal to the minimum distance between the alpha particle and the gold nucleus, which is incorrect. Nonetheless such students could still score marks for giving correct charges for the alpha particle and gold nucleus, or for converting the kinetic energy from MeV into J. In converting MeV to Joules some students had problems with powers of ten. Despite the relative unfamiliarity of the electric potential equation, some good correct solutions to this question were seen.

(b) The nuclear model of the atom was established following a series of experiments in which alpha particles were directed at thin gold foil.

kQ_1Q_2

(i) An alpha particle approaching a gold nucleus, ${}_{79}^{197}\text{Au}$, head-on will be brought to rest and returned along its original path.

Calculate the minimum distance between the alpha particle and the nucleus for alpha particles of energy of 5.5 MeV.

(4)

$$\text{Energy} = 5.5 \text{ MeV} = \frac{kQ_1Q_2}{r} = 8.8 \times 10^{-13} \text{ J}$$

$$8.8 \times 10^{-13} \text{ J} = \frac{8.99 \times 10^9 \text{ Nm}^2 \text{ C}^{-2} \times 79 \times 1.6 \times 10^{-19} \text{ C} \times 2 \times 1.6 \times 10^{-19} \text{ C}}{r}$$

$$r = 4.13 \times 10^{-14} \text{ m} \quad (3 \text{ s.f.})$$

$$\text{Minimum distance} = 4.13 \times 10^{-14} \text{ m}$$



ResultsPlus
Examiner Comments

This is a good succinct answer to the question, so all 4 marks awarded.

(b) The nuclear model of the atom was established following a series of experiments in which alpha particles were directed at thin gold foil.

- (i) An alpha particle approaching a gold nucleus, ${}_{79}^{197}\text{Au}$, head-on will be brought to rest and returned along its original path.

Calculate the minimum distance between the alpha particle and the nucleus for alpha particles of energy of 5.5 MeV.

(4)

$$\text{Charge on Au} = 79(1.6 \times 10^{-19}) \text{ C}$$

$$\text{Charge on } \alpha = 2(1.6 \times 10^{-19}) \text{ C}$$

$$E = 5.5 \text{ MeV}$$

$$= 8.8 \times 10^{-13} \text{ J} \quad * 1.6 \times 10^{-19}$$

$$F = \frac{Qq}{4\pi\epsilon_0 r^2}$$

$$W = Fd \quad F = \frac{W}{d}$$

$$\frac{F}{d} = \frac{Qq}{4\pi\epsilon_0 r^2}$$

$$r = \frac{Qq}{4\pi\epsilon_0 E} = 4.13 \times 10^{-14}$$

$$\text{Minimum distance} = 4.13 \times 10^{-14} \text{ m}$$



ResultsPlus
Examiner Comments

This response looks correct, and the answer is what we are expecting. However, the electric potential equation has not been used. Instead the method uses work done = force \times displacement with the Coulomb force equation. This cannot be correct, as the displacement of the alpha particle as it approaches is not equal to the distance between the alpha particle and the gold nucleus. However, the response can score the MP1 and MP2.



ResultsPlus
Examiner Tip

Know which of the standard equations given in the specification are listed on the formula sheet at the end of the exam paper.

Question 12 (b) (ii)

Many students were able to say that electrons were behaving like waves and that the electron wavelength was similar to the atomic spacing. Fewer gave the de Broglie equation in words as the link between these two ideas. Quite often the equation was referred to without saying what it was, or the formula was given without defining the terms. Many students made reference to wave-particle duality, but did not focus sufficiently on the wave nature (which is what this experiment demonstrates). Responses were often spoiled through lack of clarity, or, in some cases, by confusing this experiment with the Rutherford alpha particle experiment.

- (ii) It is observed that electrons, with energy of 5.5 keV, are diffracted as they pass through the thin gold foil.

Explain a conclusion about the electrons that can be made from this observation.

(3)

- They can behave like waves with a de broglie wavelength \approx the distance between nuclei
- for diffraction to occur wavelength \approx gap size
- but it must behave like a wave as diffraction is a wave phenomena



This scores MP1 and MP3, but doesn't give the link between the wavelength and the momentum.

Question 12 (c)

Many responses seen used the basic ideas outlined in the stem of the question without adding any further detail. Students did not always make it clear which electrons were elevated to a higher energy level, and some referred to the atom as gaining the energy. Energy states/levels were commonly used but the importance of the energy difference between states was not always made clear and those that did mention that the photon energy, E , was $= hf$ did not always link this to large energy difference and high frequency radiation.

A number of students thought that this was a question about nuclear fusion/fission or some other nuclear activity, and some students confused this with the photoelectric effect or ionisation. Some considered that the incident electron would be absorbed by the nucleus, make it unstable and as a result the nucleus would emit gamma radiation.

- (c) In the energy ladder model of the atom, electrons exist in a discrete number of allowed energy states. The collision of electrons with gold atoms may lead to the production of high frequency electromagnetic radiation.

Explain how high frequency electromagnetic radiation may be produced when electrons collide with atoms in a metal.

(4)

As the ~~etc~~ electrons collide with the atoms in the ~~in~~ metal the ~~metals~~ atoms become ionised where not the atoms will be looking to absorb photons and emit electrons. As $E = hf$ only ~~discrete~~ ^{discrete} frequencies and energy levels can be ~~emitted~~ absorbed. ~~As the~~ if the photon energy is higher than the work function this will make the ~~energy~~ ~~at~~ electrons to have higher KE which means it will ~~be~~ will have electrons moving at high speeds cause high frequency EM radiations.

(Total for Question 12 = 17 marks)



This response misinterprets the question, and gives an answer which seems to be an incorrect version of the photoelectric effect.



Read the question carefully to ensure that you are giving an answer to the question being posed.

- when electrons collide with atoms in a metal, the kinetic energy of the electron is converted to potential energy of the electrons in the atom, which are thus excited into a higher energy state.
- when these electrons return to their ground state, they emit this energy in the form of electromagnetic radiation, with frequencies proportional to the energy transfer between energy states.
- the em. radiation is high frequency because in order to reach the atom, the electrons colliding with the atoms must have extreme high kinetic energies.



This is a good general description of the process, although the lack of reference to photons means that it cannot score full marks.



When outlining a process you need to be clear what is happening at each stage.

Question 13 (a)

In plotting a graph, students should choose scales that spread the plotted points over more than half of the available graph paper. Difficult scales (i.e. scales increasing in "3"s, "7"s etc.) must not be used, and axes should be clearly labelled with units included which appropriate. Points should be plotted clearly (preferably using crosses) and a line of best fit drawn to show the trend.

A number of students produced clearly plotted graphs on appropriately large scaled axes, with clearly identified points on the line from which the gradient was determined. These students usually gave an expansion of the equation to show how the constants p and q were to be determined from a log or \ln graph, and used appropriate numbers of significant figures throughout. However, not all students appreciate that the same number of significant figures is required for processed data. In addition, a significant number used scales for which their plotted points did not cover more than one half of the scale each way. A few students chose to use scales in multiples of 3, which produced a difficult scale. Very few students used the correct notation for labelling the quantity $\log(D/\text{mm})$ on the axis. Points were generally plotted clearly and accurately to within half a square. For the line of best fit mark, there was a tendency to regard the first point as a pivot for the line, and there was a number of mistakes getting from the intercept to a final result. In some cases this was using the wrong base on the calculator, and in others not taking the inverse logarithm at all.

The diameter D of each circular fringe, numbered N from the centre, is measured using the microscope. The data obtained from such an experiment is shown.

N	D / mm	$\log N$	$\log(D/\text{mm})$
1	5.13	0.00	0.710
2	7.08	0.301	0.850
3	8.71	0.477	0.940
4	10.23	0.602	1.01
5	11.48	0.699	1.06

(a) The relationship between N and D is of the form $D = pN^q$ where p and q are constants.

Determine p and q for this data using a graphical method. Use the additional columns for your processed data.

(8)

$$D = pN^q$$

$$\text{gradient} = q \quad \text{intercept} = \log p$$

$$\log D = q \log N + \log p$$

$$y = m x + c$$

$$\text{gradient} = \frac{1.005 - 0.750}{0.600 - 0.090}$$

$$q = 0.500$$

$$y\text{-intercept} = \log p = 0.706$$

$$p = 10^{0.706} \approx 5.08 \text{ mm}$$

$$p = 5.08 \text{ mm}$$

$$q = 0.500$$

$\log(D/\text{mm})$

1.10

1.05

1.00

0.950

0.900

0.850

0.800

0.750

0.700

0.00

0.100

0.200

0.300

0.400

0.500

0.600

0.700

0.800

$\log(N)$





This is a good response, with all 8 marks being awarded.



You cannot take the log of a number that has units. Before taking the log divide the quantity by its unit so that it is dimensionless.

Question 13 (b)

This question assesses students' ability to calculate and combine uncertainties. In this question the half range value is expected to be used in calculating the percentage uncertainty. This is clarified in an updated section in Appendix 10 of the specification.

This question was poorly answered. In part (i) this was usually because students were using the full range rather than the half range. It was clear that many of the students do not know how to work out the percentage uncertainty in a difference between two measured values. A common method was to work out the percentage uncertainty in the two measurement and add the two values together. In addition, many students quoted their final answer to an excessive number of significant figures. Part (ii) was poorly answered, with most students stating a range of common sources of error: systematic error, parallax, poor instrument resolution, human error etc. Some wrote about the difficulty of seeing things through a microscope. Others stated that it was due to not being able to identify the centre point, not realising its irrelevance. Better responses scored a mark by referring to the irregular shape of the pattern.

- (b) The table below shows the readings from which the diameter of the first dark circle was calculated.

Position of left-hand side of circle / mm	Position of right-hand side of circle / mm	Diameter / mm
54.79	49.66	5.13

- (i) Use these readings to estimate the percentage uncertainty in the diameter due to the resolution of the instrument.

(2)

$$\frac{0.005}{5.13} \times 100\% = 0.0974\%$$

$$0.0974 \times 2 = 0.195\%$$

$$\text{Percentage uncertainty} = 0.195\%$$

- (ii) State why the actual percentage uncertainty would have been greater than the value calculated in (b)(i).

(1)

Not perfectly circular on image so more measurements would have to be made at different points to calculate mean. These measurements would have range so percentage uncertainty would be larger.



This is a good response. The steps in calculating the percentage uncertainty are clearly shown in part (i) and, in part (ii), the reason why the actual value would be greater than this is good.

Question 13 (c)

This question asks students to discuss the validity of the student's suggestion. In this context "discuss" means to consider the situation in detail and consider pros and cons of the student's suggestion.

This question was generally not well answered. A significant number of students knew that they needed to talk about coherence and were able to state the conditions for coherence, namely a constant phase relationship and the same frequency/wavelength. However, although many students were able to give the conditions for coherence, they were then unable to apply this to the given situation. Many agreed with the statement that only monochromatic light would produce interference fringes, but few understood that for each frequency present in white light the reflected waves would be coherent so a set of dark rings would be produced or a set of coloured rings would be produced. There would be different interference patterns for different frequencies present in white light. In a number of responses students simply referred to light rather than waves.

- (c) When considering the principles of this experiment, a student suggests that interference fringes would only be produced with monochromatic light. This is because interference requires coherent light waves.

Discuss the validity of the student's suggestion.

(4)

coherent light waves have the same frequency, wavelength and a constant phase difference. In order for constructive interference to occur the phase difference must be an even number of π and path difference = $n\lambda$. Constructive interference doesn't require coherent waves however destructive interference is when the waves are out of phase (an odd number of π) and have a path difference of $\frac{2n+1}{2}\lambda$. In order for complete destructive interference and to produce dark fringes, waves have to be coherent and therefore coherent.

(Total for Question 13 = 15 marks)

light waves are required to produce interference fringes.

TOTAL FOR PAPER = 120 MARKS



This response starts with a good description of what is meant by coherent waves for 2 marks. However, the response then diverges into a general consideration of the conditions for constructive and destructive interference rather than engage with what happens with light that isn't monochromatic.

- (c) When considering the principles of this experiment, a student suggests that interference fringes would only be produced with monochromatic light. This is because interference requires coherent light waves.

Discuss the validity of the student's suggestion.

(4)

If the light wasn't monochromatic, the different wavelengths would diffract a different amount so there would be multiple interference patterns overlapping, making it difficult to take measurements. Interference can still occur on non-coherent light, but the results aren't as effective. Coherent waves means they have the same frequency and a constant phase relationship.



This is quite a good response, with most of the essential detail included. There is not quite enough detail for MP3 to be awarded, so this response was given 3 marks.

Paper Summary

In order to improve their performance students should:

- Ensure that they have a thorough knowledge of the physics content of the whole specification.
- Be ready to apply their knowledge of core practicals and general techniques to questions testing their indirect practical skills.
- Read each question carefully, and answer what is asked.
- Show all their workings in calculations.

For descriptive questions:

- Make a note of the marks and include that number of different physics points.
- Try to base the answer around a specific equation or principle.

Grade Boundaries

Grade boundaries for this, and all other papers, can be found on the website on this link:

<http://www.edexcel.com/iwantto/Pages/grade-boundaries.aspx>

