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AS and A LEVEL
Exemplar Candidate Work

PHYSICS A
PHYSICS B (ADVANCING PHYSICS)

H156/H556 and H157/H557
For first teaching in 2015

Exemplar learner responses to level of response questions

Version 2

www.ocr.org.uk/physics

Contents

Introduction - General Commentary

Level of Response (LoR) questions have been used in OCR GCSE Physics examinations since 2011, and will be used in the reformed OCR GCE Physics examinations from 2016 onwards. This resource has been designed to aid teachers and learners in preparing for this style of question in their examinations.

LoR questions allow learners to be credited for both:

- their scientific knowledge, understanding and ability to apply these to familiar and unfamiliar situations, and
- their ability to communicate in a clear, coherent and logical manner.

Mark schemes for LoR questions therefore detail both the 'science content' and the 'communication' aspects of expected answers.

LoR questions are indicated in question papers with an asterisk (*) after the question number. These questions can generally be answered in many possible and equally credit-worthy ways, and therefore give learners a flexible opportunity to demonstrate their skills. As such, the indicative scientific points that are included in mark schemes are neither exhaustive nor a list of all of the scientific points that have to be included in an answer to gain a particular mark. Indeed, the mark schemes that are used to assess candidates' responses in live examinations are finalised only after examiners have looked at and discussed candidates' responses. This is a key aspect of ensuring that all candidates are awarded marks and their final grades in a fair and credit-worthy manner. The commentary included within this resource should therefore be seen within this context.

Further senior examiner commentary and guidance on answering all styles of questions is made available in Examiner's Reports (via www.ocr.org.uk) and in CPD materials (available securely to teachers via www.cpdhub.ocr.org.uk) published following each series of examinations.

For this resource, learner responses to twelve LoR questions have been marked and commented on by experienced teachers and examiners. They are taken from the sample assessment papers available on http://www.ocr.org.uk/qualifications/as-a-level-gce-physics-a-h156-h556-from-2015/ and http://www.ocr.org.uk/qualifications/as-a-level-gce-physics-b-advancing-physics-h157-h557-from-2015/.

For each question, three responses have been selected, exemplifying Level 3, Level 2, and Level 1. Commentary is provided on why the Level was selected and the mark awarded within the Level.

When assessing a learner's response, the following process is used (taken from the Marking Instructions for the H156/556 and H157/557 Sample Assessments):

For answers marked by levels of response:

- Read through the whole answer from start to finish.
- Decide the level that best fits the answer – match the quality of the answer to the closest level descriptor.

To select a mark within the level, consider the following:

- Higher mark: A good match to main point, including communication statement (in italics), award the higher mark in the level
- Lower mark: Some aspects of level matches but key omissions in main point or communication statement (in italics), award lower mark in the level.

When answering LoR questions, learners might find these tips useful:

- Read the question carefully to make sure your answer will address the question asked - underlining/circling keywords and phrases can be helpful.
- Does the question include any information/data to use in your answer?
- Think about the knowledge of Physics required and the understanding that needs to be used to answer the question – making brief notes can be helpful.
- Make your answer as logical and coherent as possible, thinking about the order in which you present your points. Diagrams and/or bullet points can be used if they help to communicate your answer(s) clearly.

The number of dotted lines given in examination papers for the answers is indicative of the length of answer expected for the question. Learners can use the extra space provided within a paper if necessary. They should, however, be cautious about writing very long answers, as this can increase the possibility of contradicting themselves and can reduce the clarity and coherence of their answers.

Please note that the level 1 descriptor in the mark schemes will be amended from June 2017 onwards to say "there is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant."

Question 1 – H157/02 Question 4(d)

AS Level Physics B Physics in depth

When the interference patterns were first observed in the nineteenth century they were interpreted as evidence for the wave picture of light. Early in the twentieth century, Albert Einstein showed that light interacts as small quanta of energy, photons. This idea is supported by the images such as **Fig. 4.6**. This shows an image of a girl's face gradually building up as more light falls on the photographic film. Image (1) is the least exposed and (6) is the most. In the early stages of building up an image the pattern is quite random.

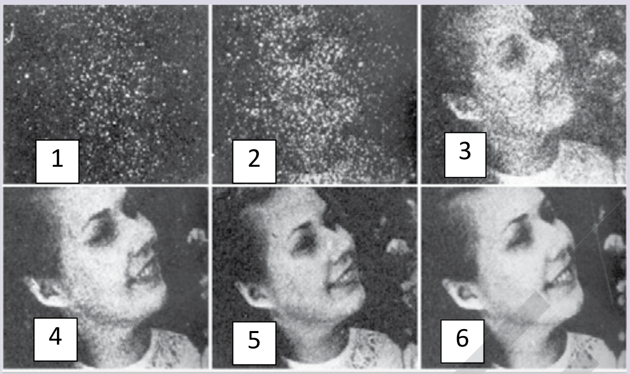

Fig. 4.6

Photons can be modelled as small quanta of energy that have a probability of arrival at a point. This probability is found by using phasors to continue the amplitude and phase for all possible paths to that point.

(d)* Describe how this phasor model can explain the gradual build-up of images such as **Fig. 4.6** and also explain two-slit interference. In your description you should also explain why a wave model cannot explain the effect shown in **Fig 4.6** and why a simple particle model cannot explain interference effects.

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Question			Answer	Marks	Guidance
4	(d)*		**Level 3 (5–6 marks)** Marshals argument in a clear manner linking the problems of wave model or simple particle model with two pieces of evidence (interference pattern and developing picture). Recognises the crucial nature of the probalistic interpretation in explaining both pieces of evidence with the phasor model. *There is a well-developed line of reasoning and the method is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Considers at least two aspects of the argument. Includes some understanding of the role of probability. *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Makes at least two independent points that are relevant to the argument. Structuring of the answer may be poor. *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* **0 marks** No response or no response worthy of credit.	6	**Indicative scientific points may include:** **Limitations of wave model:** • Image will always be the same variation of intensity as the final image. • The image will never show the random nature of the low exposures shown in the figure. Limitations of particle model: • Interference pattern requires a superposition • (classical) particles cannot superpose • No interference pattern would be observed if (classical) particles passed through the slits. Phasor model: • Interference pattern can be explained by adding phasors from the two slits • Recap of phasor explanation of interference pattern using ideas from earlier in the question • This gives a probability of arrival, not a (simple) wave amplitude • Because the resultant amplitude gives a probability of arrival it explains the random nature of the early exposures.

Candidate response 1. Level 3, 6 marks

The phasor model considers each path taken by the photons and works out a probability of arrival at a specific point by adding all the phasors and working out the 'resultant' an 'amplitude'. If the amplitude is small (phasors curl up) there is a small (nearer to zero) probability of arrival. If the phasors line up there is a greater probability of arrival.

The grainy picture gets smoother over time as more photons arrive, some paths will have a higher probability than others, hence the grainy image at the start. If you tried to use the wave model to explain this you would expect the initial image to be a fainter and smoother version of the end image as seen in 6. This is not what we see.

With the double slit experiment we observe a fringe pattern (bright and dark regions), with areas of high probability of arrival (bright) and low probability of arrival (dark). For this to happen superposition needs to take place which is explained with the wave model, but cannot be explained through the particle behaviour model.

Commentary

This is a higher band answer, with clear arguments that link problems of both models with the observations. The phasor model is used well.

What the candidate did well

The candidate outlines the idea of phasors and their probabilistic nature, and the problems associated with both the wave model and particle model in explaining the two-slit experiment and the developing picture.

Candidate response 2. Level 2, 3 marks

The idea of phasors and quanta explains why the picture is grainy, as the photons arrive randomly based on their probability of arrival.

The wave model would mean that over time the exposure would become clearer as the brightness would increase in a uniform way, which is not what we see from the images in figure 4.6.

The particle model cannot explain interference as for interference to happen you have to have superposition and I don't think particles can superimpose.

Commentary

The candidate omits the explanation of two slit interference, and discusses the idea of superposition incompletely, with no reference to phasors. The ideas on photons are lifted directly from the question, and shows limited understanding of the role of probability in both observations. As a result this is a lower Level two answer.

What the candidate did well

The candidate presents problems with each model in explaining the observations.

How the answer could be improved

The candidate could use the phasor model, as outlined in the question, to explain the observations for both the images seen and interference.

Candidate response 3. Level 1, 1 mark

Two-slit interference results in an interference pattern as light passes through two slits. The waves that pass through the slits interfere giving destructive (0, dark area) and constructive interference (1, a bright area). Measurements from the pattern can be used to find the wavelength of the light. Particles can't interfere so you can't explain the pattern seen this way. Phasors can be used to explain this, and the pixely image

Commentary

The candidate describes the wave model explanation of interference, albeit incompletely, and suggests a limitation in the particle model. This is a lower band answer as the candidate fails to make relevant points about the image and explain this using the phasor model.

What the candidate did well

The candidate addresses the observations from the two-slit interference partially.

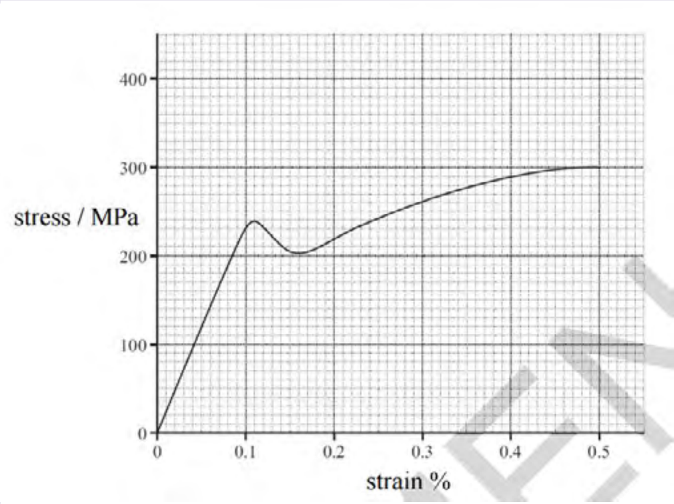
How the answer could be improved

The candidate should ensure they address the question asked. Using idea about phasors and both the wave and the particle model in the different situations would also improve this answer further.

Question 2 – H157/02 Question 5(d)

AS Level Physics B Physics in depth

(c)* **Fig.5.2** shows a stress-strain graph of the same material, obtained from a tensile testing machine.



(i) Mark with an X the point on the graph in **Fig. 5.2** where plastic deformation begins. **[1]**

(ii) State the feature of the graph that represents the stiffness of the material and describe how the stiffness varies between a strain of 0.2% and 0.5%.

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(d)* Steel is an alloy. Its main constituent is iron. Using ideas about dislocations and metallic structure explain why the steel first shows the elastic behaviour (up to point X) and then shows plastic behaviour (beyond point X). Elaine how the presence of atoms other than iron makes the resulting metal harder and less plastic than pure iron.

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Question			Answer	Marks	Guidance
5	(d)*		**Level 3 (5–6 marks)** Marshals argument in a clear manner giving clear reasoning at all points. Each part of the question fully covered and the connection made between elastic behaviour, plastic behaviour and allowing in microscopic terms. *There is a well-developed line of reasoning and the method is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Considers at least two aspects of the argument. May not link the aspects together. Shows understanding of the basic model of a metal. *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Makes at least two independent points that are relevant to the argument. Structuring of the answer may be poor. *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* **0 marks** No response or no response worthy of credit.	6	**Indicative scientific points may include:** **Elastic behaviour** • metal described as positive ions in a sea (AW) of free electrons • interatomic (interionic) spacing increasing as metal is put under tension • this increase in spacing is uniform (parallel to tension) • when tensile force removed atomic separation returns to initial values • no energy lost in stretching and relaxing elasticity. **Plastic behaviour** • planes of atoms slide (AW) over one another • dislocations allow plastic behaviour to occur at a lower stress • dislocation allow bonds to be broken one bond at a time. **Effect of Alloying** • foreign/guest atoms pin down dislocations • this makes slip less likely/ planes move over shorter distances.
			Total	**14**	

Candidate response 1. Level 3, 5 marks

As a metal, iron has a rather crystalline structure made up of iron atoms held together by metallic bonds. As a result iron alone, with the presence of dislocations, is malleable. Steel however, an alloy which main constituent is iron, will be more stiff than iron as the dislocations have been pinned, so the layers of atoms are less likely to slip. Steel shows elastic behaviour up until point X, meaning that the atom spacing is able to extend with a force and then go back to its original length once the steel is removed. This is because, due to metallic bonding the positive ions are surrounded by a sea of free electrons, and so once the force is removed they return to their original position. If you apply too much force to the steel (beyond X), then the layers of atoms will move over each other and in a pure metal the dislocations let sections of the layer of atoms (or individual atoms) to move, so with an alloy where the dislocations are pinned, the movement of layers is less likely and so steel is less plastic than iron.

Commentary

The candidate addresses the difference between iron and steel and mentions dislocations appropriately. Both elastic and plastic behaviour in microscopic terms are addressed well.

What the candidate did well

The candidate describes and explains how the bonding allows for both elastic and plastic behaviour. Although the dislocation terminology is inconsistent, the ideas are correct.

How the answer could be improved

The candidate repeats themselves, and with better planning could have formed a more succinct answer, for example, the mentioning metallic bonding and then describing it later on could have been brought together.

Candidate response 2. Level 2, 3 marks

In the steel there are layers of iron with atoms of carbon pinning the dislocations, stopping them from moving when a force is applied. If the dislocations were not pinned in place, the layers could slide over one another more easily, this is why steel is harder and less plastic. Up to point X, the atoms can only move so far, however past this point the atoms can slide past each other.

Commentary

Some key ideas communicated effectively, but the description of basic metallic structure is omitted, and does not allow the candidate to access the higher levels. The points made are relevant to the argument, but lack detail. The candidate appears to have an understanding of the basic structure of a metal and an alloy, even if they have not communicated this as well as they could have. For this reason, they are awarded three out of six, but could not be higher..

What the candidate did well

Plastic behaviour in steel is explained effectively with reference to dislocations and their pinning.

How the answer could be improved

The candidate has answered the question with reference to dislocations only, without explaining what they are, and has not considered the bonding. In their answer the idea of elastic behaviour of iron is inferred and mentioned briefly, but not explicitly. Discussion on plastic behaviour is basic and could be explained further, highlighting the difference between iron and steel.

Candidate response 3. Level 1, 1 mark

As the metal is stretched, more and more dislocations within the metal are created, when it gets up to certain point, the metal can't be put back to its original shape. This is what we call plastic deformation. After this, it changes much slower. When there is another atom within the metal it creates a block in the dislocation hole and makes the material harder as atoms can't move as far.

Commentary

The candidate does not describe the structure of metals and what a dislocation is, or how it affects the properties of the material. The idea of a limit is there, but is incorrectly explained. This is a very low level answer, and although two relevant points are made, key terminology is not used well.

What the candidate did well

The idea of pinning a dislocation is implied, even if it is not explained.

How the answer could be improved

The candidate does not describe the difference between iron and its alloy steel, but appears to assume that this is understood. Elastic and plastic behaviour could be explained and then the impact of pinning dislocations highlighted.

Question 3 – H157/02 Question 6(f)

AS Level Physics B Physics in depth

SECTION C

Answer **all** the questions

6 This question is about an experiment performed in AS physics to determine the internal resistance of a battery (two cells combined in series). The experiment can be set up as shown in **Fig. 6.1**.

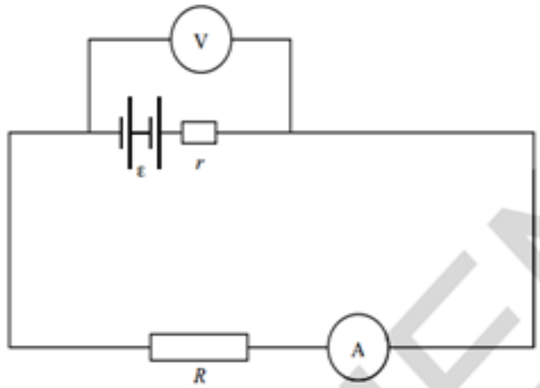

Fig. 6.1

Measurements of p.d. V and current I for a range of values of resistors R are taken in order to determine a value for the combined internal resistance of the cells.

(f)* A student suggests three possible variations to extend the experiment.

1) Adding a switch into the circuit so that the circuit can be disconnected between readings.
2) Adding another cell.
3) Reversing one of the cells.

Discuss the effect that each of these three suggested changes would have on the accuracy of the experiment, the uncertainty of measurement and the data collected.

Question			Answer	Marks	Guidance
6	(f)*		**Level 3 (5–6 marks)** Constructs argument in a clear manner giving clear reasoning at all points. Each part of the question fully covered and the connection made with data on the graph. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Covers at least two aspects of the argument. May not link the aspects together. Shows understanding of the effect on uncertainties. *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Makes at least two independent points that are relevant to the argument. Structuring of the answer may be poor. *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* **0 marks** No response or no response worthy of credit.	6	**Indicative scientific points may include:** **Adding switch** • Idea of reducing heating effect • No energy lost/draining of the battery/cells. • Improved reliability **Adding another cell** • Increase in pd -> increase in current • Change to the overall resistance • % uncertainty in current reading reduces • Graph would have a steeper gradient and higher intercept **Reversing the cell** • Reduces the pd -> reduces the current flow • % uncertainty would increase. • Overall internal resistance would be the same • Would produce a lower intercept but same gradient.

Candidate response 1. Level 3, 5 marks

By putting a switch in, there is less risk of getting electrocuted, which is good. It will also mean that the battery will take longer to run out, so you may be able to get some good repeat results. Adding another cell means the circuit will have a lot more voltage running through it which should mean that you can get a larger spread of data. A higher potential difference will also mean that there is a higher current, which should reduce the % uncertainty in the current readings, and on the graph would give a bigger y-intercept, but also a larger value for r (gradient) Reversing one of the cells will result in no potential difference so no current will flow, unless the original set up held, and the added cell (variant 2) is added in reverse, in which case it will have the opposite effect to the addition of the cell discussed above; the % uncertainty in current measurements will increase as less potential difference and hence a lower current flows.

Commentary

The candidate discusses each of the variations and supports with reference to the data represented on the graph. Most of the information given is well reasoned and relevant. This is a good response, but the final mark was not awarded as the candidate failed to consider the accuracy of the data collected fully.

What the candidate did well

The candidate recognises and discusses the variations methodically, suggesting how these changes impact the % uncertainty and relates these to the graphical plots clearly.

How the answer could be improved

Some irrelevant details included. Candidate does not discuss the idea of accuracy fully. Overall this was a higher band response, which addressed the main concepts well in an organised manner.

Candidate response 2. Level 2, 3 marks

These 3 changes will impact the data collected.

1. Adding a switch will mean you can turn off the current, which will reduce the heat, allowing it to cool down between readings, and so increase the accuracy, and will mean that the cells will not drain too quickly, so the data should be more reliable as you could take repeats. The switch would also have its own resistance which may cause problems.
2. Adding another cell would reduce the uncertainty and increase the accuracy, because of the increase the voltage. On the graph it would scale up.
3. Switching the cell around means that the two cells are in opposite polarity so no current will flow, meaning no results will be able to be taken.

Commentary

The candidate considers the three variations to the experiment, and the points made are generally relevant, and well structured, with a few distracting features. Two aspects of the argument are covered with correct statements with reference to quality of data. Some of the statements are vague and lack clarity and hence the three rather than the four marks awarded.

What the candidate did well

The candidate considers the changes and the impact of these on the quality of the data collected. An incomplete attempt is made to discuss the effect on data in the graph.

How the answer could be improved

The candidate could have referred to the changes to the experimental data in more detail and how the graph changes as a result. Explanations for the changes to uncertainty are unclear.

Candidate response 3. Level 1, 1 mark

1. The battery would get less flat
2. This would add more voltage, meaning that you have less relative uncertainty
3. This would stop it working – why would you do this?

In conclusion, 2 is a pretty good idea, but I wouldn't recommend the others.

Commentary

The candidates answer is brief, in statement form, and considers the variations with the experiment, with a view to improving the data. There is no further discussion on the impact, better or worse, on the accuracy, uncertainty or data collected. No attempt is made to connect the variations with the graphical data. One mark was given for making two independent relevant points, but benefit of the doubt is given for the second variant as the student has failed to state which variable has 'less relative uncertainty', this, and the lack of relationship with the graph, meant that the second mark could not be awarded. Overall this was a weaker lower band response, which failed to discuss the ideas presented fully.

What the candidate did well

The candidate recognises the advantages of two of the variations, and suggests which may improve the experiment.

How the answer could be improved

The candidate could have referred to the experimental data given earlier in the question and discussed how this data could be effected by the variations suggested.

Question 4 – H156/02 Question 7(a)

AS Level Physics A Depth in Physics

7 **(a)*** The Planck constant h can be measured in an experiment using light-emitting diodes (LEDs).

Each LED used in the experiments emits monochromactic light. The wavelength λ of the emitted photons is determined during the manufacturing process and is provided by the manufacturer.

When the p.d. across the LED reaches a specific minimum value V_{min} the LED suddenly switches on emitting photons of light of wavelength λ.

V_{min} and λ are related by the energy equation $eV_{min} = hc/\lambda$.

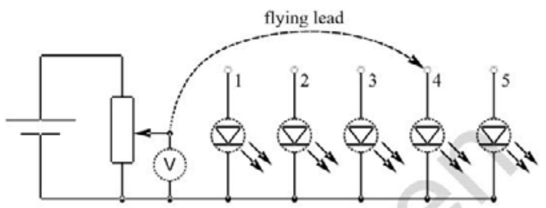

Fig. 7.1

LED	λ/nm	V_{min}/V
1 red	627	1.98
2 yellow	590	2.10
3 green	546	2.27
4 blue	468	2.66
5 violet	411	3.02

Discuss how you could use the circuit of **Fig. 7.1** to determine accurate values for V_{min} and how data from the table can be used graphically to determine a value for the Planck constant.

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Question			Answer	Marks	Guidance
7	(a)*		**Level 3 (5–6 marks)** at least E3, 4 and 2 or 5 at least P1, 2 and 5 *This is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** expect 3 points from £ and 2 points from P or 2 points from E and 3 points from P *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* **Level 1 (1–2 marks)** at least 2 points from E and 1 point from P or vice versa. *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* **0 marks** No response or no response worthy of credit.	**B1** **x6**	**Experiment (E)** 1. Adjust the potential divider to low or zero voltage. 2. connect flying lead to one LED 3. increase voltage until LED just lights or strikes 4. repeat several times and average to find V_{mn} 5. repeat for each LED 6. shield LED inside opaque tube to judge strike more accurately. **Processing (P)** 1. a graph of V_{mn} against $1/\lambda$ will be a straight line 2. through the origin 3. so need to calculate the values of $1/\lambda$ 4. then draw the line of best fit through origin 5. gradience $G = V_{mn}\,\lambda = hc/e$ 6. hence $h = eG/c$

Candidate response 1. Level 3, 6 marks

Use a darkened roll of paper to look at LED or use a darkroom so you can see when it just comes on. Connect flying lead to 1

Decrease rheostat from max resistance downwards

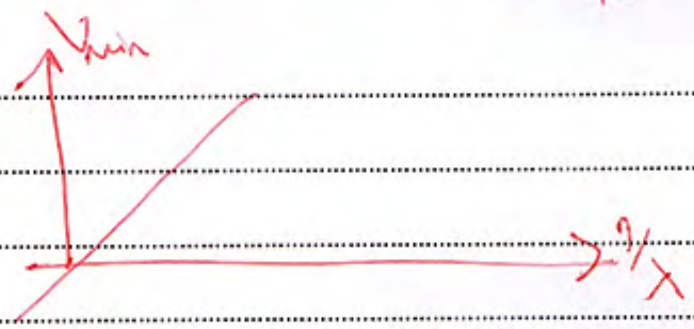
~~Take~~ ~~[illegible]~~ Read PD on (V) when it lights.

Repeat 5 times & take average.

Repeat with flying lead connected to 2–5.

$$eV_m = \frac{hc}{\lambda} \Rightarrow V_m = \frac{hc}{e} \times \frac{1}{\lambda}$$

Plot



gradient $= \frac{hc}{e}$

$\therefore h = \frac{e}{c} \times$ gradient

Commentary

This response shows a clear and logical line of reasoning. The answer is structured in terms of experimental design > measurements > processing of results, and it is clear how to determine a value for the Planck constant using a graphical method. The response is clearly in level 3.

In the 'Experiment' section (E), the student has made an attempt at E1 and E3 but does not fully explain the potential divider arrangement. They have gained E2, E4, E5 and E6 so this is definitely a level 3 response. However, to ensure full marks, the student should talk about adjusting the potential divider to zero voltage and then increasing the voltage.

In the 'Processing' section (P), the student has gained P1 and P2 (via the graph), P5 and P6. This is a high level 3 response.

Overall, this response would just score the full 6 marks.

Candidate response 2. Level 2, 4 marks

You would connect the flying lead to each LED independently, and then vary the voltage util the light starts to show. This is the minimum voltage, threshold frequency. Next you would need to plot a V, against 1/λ graph. The wavelength value is provided, ~~no~~ so no need to calculate it. The gradient of your graph would equal $\frac{hc}{e}$. To get Plack's constant from this you would multiply your gradient by e, then divide by c. The graph should show a straight line which passes through the origin.

Commentary

There is some structure to the response and it has a line of reasoning, but the links are not always clearly made. For example, 'This is the minimum voltage, threshold frequency' is too vague a statement, and 'The wavelength value is provided, so no need to calculate it' misses the point that 1/λ does need to be calculated in order to be able to plot the graph. In order to reach the top level, the student would need to add more experimental detail and structure the first part of the answer more carefully.

In the 'Experiment' section (E), the student has included E2, E5 and an attempt at E3 ('Vary the voltage until the light starts to show'). In the 'Processing' section (P), they have included P1, P2, P5 and P6.

Three points from E and at least 2 from P puts this answer in level 2. It is high in the level 2 band (4 marks), but does not quite reach level 3 because the student has not included E4. To improve the answer, therefore, the student should mention repeating several times and finding an average value for V_{min} each time.

Candidate 3. Level 1, 2 marks

The variable resistor could be set to max, then slowly decreased until LED 1 (red, requiring a lower voltage as it has a larger wavelength) begins to emit light. The ~~pote~~ reading on the voltmeter at this point is the potential difference required to "just" turn on the LED, the specific minimum V_{min}. This could be repeated for all the LED's ~~to~~ to obtain the data shown in the table.

If $eV_{min} = \frac{hc}{\lambda}$, then $V_{min} = \frac{hc}{e} \times \lambda^{-1}$

If we plot a graph of V (p.d.) to λ^{-1}, the gradient of this graph would be equal to $\frac{hc}{e}$

Commentary

There is a clear line of reasoning in this response, since the answer is structured in terms of experimental design → processing of results. However, there are some gaps in the reasoning (for example, the diagram shows the flying lead connected to LED 4, whereas the answer says that LED 1 would begin to light).

In the 'Experiment' section (E), the student has made an attempt at E1 and E3 but does not fully understand the potential divider arrangement. They have fully gained E5.

In the 'Processing' section (P), they have made an attempt at P1 ('the gradient of this graph' implies a straight line graph) and they have gained P5.

This response does not quite reach level 2 as there is only one clear point from each of E and P. The student would have to develop E1, E3 and P1 further in order to gain the '3 points from E and 2 points from P' needed for level 2.

Overall, this response is at the high end of level 1 and would gain 2 marks. To improve the answer, the student should add more experimental and processing details, and describe how h can be calculated from the gradient measurement.

Question 5 – H556/01 Question 18(a)

A Level Physics A Modelling Physics

18 (a)* A group of scientists have designed an alloy which is less dense than copper but may have similar mechanical properties. A researcher is given the task to determine the Young modulus of this alloy in the form of a wire.

Write a plan of how the researcher could do this in a laboratory to obtain accurate results. Include the equipment used and any safety precautions necessary.

Question			Answer	Marks	Guidance
18	(a)*		**Level 3 (5–6 marks)** All points E1, 2, 3 and 4 for equipment All points M1, 2, 3 and 4 for measurements For calculations expect C1, C2, C3 and C4. *This is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Expect E1 and E2; E3 or E4 for equipment Expect M2 and two from M1, M3 M4 for measurements For calculations expect at least C3 and C4 Expect at least one point from reliability *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Expect at least E1 and E2 for equipment Expect at least two from measurements Expect C5 for the calculation No real ideas for obtaining reliable results *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* **0 marks** No response or no response worthy of credit.	**B1 x6**	The complete plan consists of four parts: **Equipment used safely (E)** 1. Wire fixed at one end with load added to wire 2. Suitable scale with suitable marker on wire 3. Micrometer screw-gauge or digital/vernier callipers for measuring diameter of wire 4. Referencing to safety concerning wire snapping **Measurements (M)** 1. Original length from fixed end to marker on wire 2. Diameter of wire 3. Measure of load 4. New length of wire when load increased **Calculation of Young modulus (C)** 1. Find extension (for each load) or strain (for each load) 2. Determine cross-sectional areas or stress 3. Plot graph of load-extension **or** graph of stress-strain 4. Young modulus = gradient x original length/ area **or** Young modulus = gradient 5. Calculate Young modulus from single set of measurements of load, extension, area and length. **Reliability of results (R)** 1. Measure diameter in 3 or more places and take average 2. Put on initial load to tension wire and take up 'slack' before measuring original length 3. Take measurements of extension while unloading to check elastic limit has not been exceeded. 4. Use log wire (to give measurable extension) Scale or ruler parallel to wire

Candidate 3. Level 3, 5 marks

Equipment needed: ruler, long wire, micrometer, variable masses (e.g. slotted masses)

Safety: wear goggles and gloves incase wire snaps under too much weight. Be careful not to drop weights on feet.

Method: Measure radius of wire in several places using micrometer. Radius = $\frac{1}{2}$ diameter. Work out average cross-sectional area of wire = πr^2, r = average radius of wire. Hang the wire from the ceiling. Measure length of wire using ruler. Attach different masses to wire and measure its extension. Extension = length − original length = ΔL. Varying the masses allows to vary the force acting on the wire. Measure the force on wire in Newtons.

Calculations: Plot a graph of F against ΔL. This should be a straight line. Young Modulus = $\frac{\text{Stress}}{\text{Strain}}$; $E = \frac{F/A}{\Delta L/L}$

Gradient of the graph is $\frac{F}{\Delta L}$ $E = \frac{FL}{A\Delta L}$, so $E = \frac{\text{gradient} \times L}{A}$

L = original length of wire, A = cross-sectional area of wire. gradient is worked out from $F/\Delta L$

Commentary

There is good structure to this response with the use of sub-headings ('Equipment needed', 'Safety', 'Method' and 'Calculations'). The reasoning is clear and well-developed and the student explains how to calculate the extension and the cross-sectional area of the wire. The student uses a graphical method to determine the Young modulus and clearly explains how to calculate this from the gradient. This response is clearly in level 3.

In the 'Equipment used safely' section (E), the student has included E1, E3 and E4 in their answer, which is only a level 2 response. To improve their answer, they must also include E2.

In the 'Measurements' section (M), they have made an attempt at M1 ('Measure the length of the wire using a ruler') and they have included M2, M3 and M4. This is a low level 3 response.

In the 'Calculations' section (C), they have included C1 – 4, which is a high level 3 response.

In the "Reliability of results' section (R), they have included R1 and R4, which is a low level 3 response. To improve their answer, more points about reliability should be made.

Overall, although this response is in level 3, the student has not performed well enough in the E and M sections to gain full marks.

Candidate 2. Level 2, 3 marks

Wear Safety goggles at all time during the experiment to prevent wire damaging the eyes. Set up a stand and a Clamp to hold the top of a wire. Measure the diameter of the wire using a micrometre and use this value to find cross sectional area by area $= \pi\left(\frac{D}{2}\right)^2$. Measure the original length of the wire in cm, Now add a weight of 1N, and measure new length. Repeat this for masses up towards its limit. Do not exceed its limit because if the wire snaps it could damage your eyes.

- Measure excesin average.
- ~~cross~~ Stress = Force / area
- Strain = Exctisn / original length.

$$YM = \frac{\text{Stress}}{\text{Strain}}$$

Commentary

The student presents a clear line of reasoning with a good structure. Everything the candidate says is relevant and they give us some information (such as how to calculate the cross sectional area of the wire). However their answer is fairly short and basic and lacks the detail which characterises a level 3 response. For example, they have not used a graphical method to calculate the Young modulus. So this response would be somewhere in level 2.

In the 'Equipment used safely' section (E), the student has included E1, E3 and E4 but has not included E2. This would qualify as a low level 2 response in terms of equipment. To gain E2 and so improve their answer to the top level, they should include a ruler parallel to the wire in their list of equipment, and add a suitable marker on the wire.

The student has performed well in the 'Measurements' section (M) and has included all measurements M1 – 4, which is a high level 3 response.

In the 'Calculations' section (C), the student's calculation is limited but does include C2 and C5, reaching a high level 1. In order to reach level 2, they should be using a graphical method to determine the Young modulus.

In the 'Reliability of results' section (R), the student has made no mention of how to obtain reliable results, which indicates a level 1 response. They have mentioned measuring the 'extension average', but this is not sufficient for R3.

Overall, since the student's C and R sections are both only at level 1 and they have not used a graphical method to calculate E, their answer is at the low end of level 2 and would gain 3 marks overall.

Candidate 3. Level 1, 2 marks

The Young modulus of the material is the stiffness of the material. The researcher should clamp a long piece of wire on a table and measure a part of the wire ~~using a~~ from the clamp using a ruler, then attach a mass to the other end of the wire and measure how far the point has extended from its original position, you can use the mass to work out the force applied by the mass, and you could work out the cross-sectional area using a micrometer, using this information Young Modulus $= \frac{\left(\frac{F}{A}\right)}{\left(\frac{x}{L}\right)}$

Commentary

This answer has some structure but the information that it provides is basic. The student informs us that we 'can use the mass to work out the force' and that we 'could work out the cross-sectional area', but they do not actually tell us how to do so. This answer is clearly in level 1.

In the 'Equipment used safely' section (E), the student has included E1 and E3 in his answer, which is a low level 1 response. To improve the answer, they must also include E2.

In the 'Measurements' section (M), they have included M1 and made an attempt at M3 ('you can work out the force applied') and at M4 ('measure how far the point has extended from its original position'). This is again a low level 1 response.

In the 'Calculations' section (C), they have included C2 and C5, which is a high level 1 response. To improve his answer, they should use a graphical method to calculate the Young modulus.

In the "Reliability of results' section (R), they have included R4 ('clamp a long piece of wire'), which is a low level 2 response. However, since E, M and C are all in level 1, this answer can only gain 2 marks.

Question 6 – H556/01 Question 23 (c)

23c * The Big Bang theory is an explanation for the start of the Universe.

Explain how the cosmic microwave background radiation supports the Big Bang theory for the start of the Universe.Comment on the relevance of the data in **Fig. 23.1** concerning the Big Bang theory.

Fig. 23.1 gives some data on the wavelength of a hydrogen spectral line for light received from the Andromeda galaxy and the Virgo cluster of galaxies.

	wavelength of hydrogen line from galaxy / nm	wavelength of hydrogen line on Earth / nm
Andromeda galaxy	485.6	486.1
Virgo cluster	489.8	486.1

Fig. 23.1

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Question			Answer	Marks	Guidance
23	(c)*		**Level 3 (5–6 marks)** Expect T1 and T2 for the Big Bang Theory Expect full discussion of red shift points R1, 2, 3 and 4 Expect at least B1 and B2 for the Blue Shift Expect C1 and any three from C2, C3, C4, C5 for CMBR *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Expect T1 and T2 for the Big Bang Theory Expect R1 and R2; red shift identified but no explanation why it implies an expanding Universe Expect B1 and B2; blue shift identified with no explanation of cause Expect any three from C1, 2, 3, 4 and 5; CMBR evidence recalled but linked to the Big Bang *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Expect T1 or T2 for the Big Bang Theory Expect R1, R2 or B1, B2; red shift or blue shift identified but without explanation or link to Big Bang Theory Expect at least one from C1, 2, 3, 4 and 5; CMBR evidence recalled but not linked to the Big Bang ***The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.*** **0 marks** No response or no response worthy of credit.	**B1 x6**	**Big Bang Theory (T)** 1. Predicts that all galaxies will be receding. 2. Galaxy velocity proportional to distance from Earth. **Red Shift (R)** 1. Radiation from Virgo shows increase in wavelength or red shift 2. Change in wavelength caused by motion of galaxy or reference to Doppler Effect 3. Evidence that Virgo is receding from Earth. 4. Support for Big Bang theory. **Blue Shift (B)** 1. Andromeda shows blue shift 2. Andromeda approaching Earth 3. Caused by gravitational attraction. **CMBR (C)** 1. Formed as gamma radiation at Big Bang 2. Galactic red shift to microwave wavelength 3. Intensity is uniform in all directions 4. Corresponds to a temperature of 2.7K 5. (Very small) ripples in intensity corresponding to formation of first stars or galaxies.

Candidate response 1. Level 3, *marks

486.1 | redshift & distant galaxies

Fig. 23.1

The cosmic microwave background radiation is an image that shows tiny temperature variations from the very early universe. It shows that high energy gamma photons have had their wavelengths stretched due to the expansion of space. This means that space was once much smaller. The universe must have been very hot and dense when it was younger and it has now cooled to around 2.7K. The data in Fig 23.1 proves Hubble's law as his law only applies to distant galaxies. The light from our neighbouring galaxy has been blue shifted as it moving towards us (due to gravitational attraction). The light from the Virgo cluster has been red shifted, explained by the doppler effect. This shows distant galaxies are accelerating away from us due to the expansion of space which supports the Big Bang theory as this means the universe was once much smaller. [6]

Commentary

This answer is easy to follow and it is logically structured (e.g. the light from our neighbouring galaxy has been blue shifted (B1) as it is moving towards us (B2), due to gravitational attraction (B3)). It contains plenty of detail too. However, since the question asks for comments on how the CMBR and the data support the Big Bang theory, it would be an excellent idea to start the answer with a description of what the Big Bang theory actually states and predicts.

Candidate response 2. Level 2, 3 marks

Fig. 23.1

When the universe began it would have been extremely hot and filled ~~extrem~~ abundantly with high energy gamma photons. But now, 14 billion years later, space has cooled and has stretched over time, this expansion elongated the wavelengths of gamma photons such that they are now observed as being microwaves. As for the relevance of the data: ~~AΔ = V~~ the Andromeda galaxy displays signs of blue shifting IE moving towards us ~~th~~ but the Virgo cluster displays red-shifting and this would support the idea of an expanding universe as it must be moving away, and thus by extension the big bang. Therefore the data found in fig 23.1 is of extreme relevance as it shows good evidence for the ~~big~~ Big Bang. this is due to the fact that the velocity of a galaxy is proportional to its distance from Earth. [6]

Commentary

This answer has some structure but the logic is faulty in places. For example, it claims that the data shows good evidence for the Big Bang, due to the fact that the velocity of a galaxy is proportional to its distance from Earth. In fact, the data shows no such thing. However, the description of the source of the CMBR is relevant, and the candidate has appreciated that the Andromeda Galaxy shows a blue shift whereas the Virgo cluster shows a red shift.

Candidate response 3. Level 1, *marks

Fig. 23.1

the microwave background radiation supports the big bang theory as it can only be proved by that theory that proves it. It supports the ~~idet~~ idea that when the universe ~~is~~ was young and very hot. the radiation was high energy photons. As time went on and the universe expanded and cooled, this caused the wavelength to stretch to what it is observed as now. The wavelength data is relevant as it can be used to calculate the recessional velocity of the galaxies ($\frac{\Delta\lambda}{\lambda} = \frac{v}{c} \rightarrow \frac{\Delta\lambda c}{\lambda} = v$). These ~~fr~~ will prove the universe is expanding in all directions

[6]

Commentary

This answer is confused and lacks detail. For example, in the CMBR section in the mark scheme, points C1, C3, C4 and C5 are all missing. The candidate claims that the data will prove that the universe is expanding in all directions, and has not noticed that the Andromeda Galaxy actually shows a blue shift. However, the answer deserves to be placed in level 1 since the candidate has some understanding of the conditions at the time of the Big Bang and the effect of the expansion of space.

Question 7 – H556/02 Question 17 (c)

Fig. 17.3 shows how the resistance of a thermistor varies with temperature.

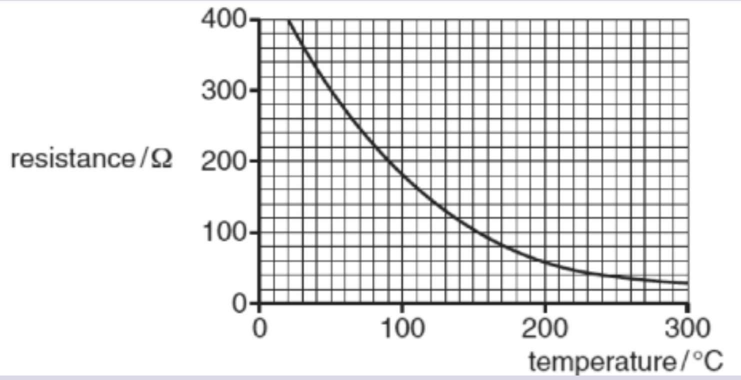

Fig. 17.4 shows a potential divider circuit which uses this thermistor. The circuit is designed to monitor the changes in the temperature of an oven in the range 200°C to 300°C.

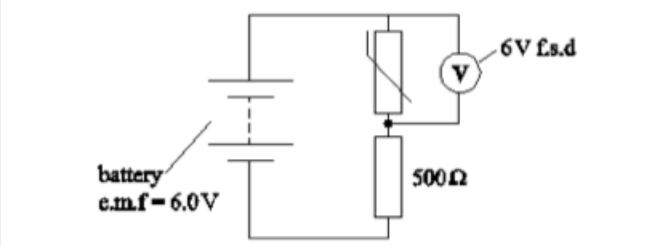

Fig. 17.4

The voltmeter has very high resistance and has a full scale deflection (f.s.d.) of 6.0 V.

Explain how the circuit works and use calculations to discuss a significant limitation of this design.

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Question			Answer	Marks	Guidance
17	(c)*		**Level 3 (5–6 marks)** Explanation is complete with E1, 2 and 3 For calculation expect C3 At least two limitations mentioned. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Expect two points from E1, 2 and 3 Expect either C1 or C2 for the calculations Expect at least one limitation Limitation identified but calculations are inappropriate. *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Expect at least one point from explanation Expect C1 and an attempt at C2 Limitations given are inappropriate. *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* **0 marks** No response or no response worthy of credit.	**B1 x6**	**Explanation (E)** 1. Total resistance decreases as temperature increases (allow reverse argument) 2. Current in circuit increases as temperature increases or p.d. is in the ratio of the resistance values 3. Therefore, the p.d. across resistor increases or p.d. across thermistor decreases. **Calculations (C)** 1. $I = V/R$ used to show current increases as temperature increases 2. Potential divider equation (or $I = V/R$ and $R = R_1 + R_2$) used to calculate the voltmeter reading at either 200°C or 300°C • $V_{300} = 6.0 \times 25/(25+500) = 0.29$ V • $V_{200} = 6.0 \times 60/(60+500) = 0.64$ V) 3. Potential divider equation used to calculate the voltmeter reading at both 200°C and 300°C **Limitation (L)** 1. The change in resistance is small when resistance of thermistor changes from 200°C to 300°C 2. Change in voltmeter reading is too small over this range 3. Non-linear change of resistance with temperature.

Candidate response 1. Level 3, 5 marks

17c

As the temperature increases, the resistance of the thermistor decreases [Fig 17.3] and so the total resistance in the circuit falls. This increases the current through the series circuit [V = IR ; V constant so $I \propto 1/R$]. The PD across the 500Ω resistor increases, so the PD across the thermistor must decrease (since they are in series and $R_T = R_1 + R_2$). This means that the voltmeter reading falls.

At 200°C, $R_{thermistor} = 60\Omega$

$$\frac{V_{therm}}{6} = \frac{60}{560} \Rightarrow V_{therm} = 0.64V$$

At 300°C, $R_{thermistor} = 30\Omega$

$$\frac{V_{therm}}{6} = \frac{30}{530} \Rightarrow V_{therm} = 0.34V$$

A limitation is that there is very little variation in the voltage output, and it would be especially hard to see using a voltmeter of 6V fsd.

[6]

Commentary

This answer is very clearly set out and logically structured (e.g. as the temperature increases … the total resistance in the circuit falls (E1) … this increases the current through the series circuit (E2) … so the PD across the 500Ω resistor increases (E3)). The potential divider equation is used accurately at both temperatures and a valid limitation is identified. However, further discussion of limitations would improve this answer.

Candidate response 2. Level 2, 3 marks

When the temperature increases, the resistance of the thermistor decreases, so the voltage ~~on~~ across the thermistor decreases. The limitation is that the resistance does not change much ~~beyond~~ between 200°C & 300°C. At 200°C, the resistance is ≈ 80 Ω & at 300°C R ≈ 30 Ω ∴ the ~~voltage~~ readings on the voltmeter are $\frac{80}{580} \times 6 = 0.828$ V and $\frac{30}{530} \times 6 = 0.340$ V respectively. This change in voltage over the temperature range is extremely small to be read on a voltmeter with a f.s.d. of 6V.

[6]

Commentary

This answer has a sketchy explanation section ('the resistance of the thermistor decreases, so the voltage across the thermistor decreases' does not follow as it stands without additional logical steps). However, the answer does have some structure. The voltmeter reading at both temperatures has been attempted (C3), but the calculation at 2000C is inaccurate.

Candidate response 3. Level 1, 1 marks

the idea is that when the oven heats up, the thermistor's resistance will decrease, allowing more current to flow to the rest of the circuit, when it's cold current will flow to the voltmeter. The limitation is that not all current will flow when the oven is hot and the resistance barely changes at low temperatures, leading to a very small change in voltage.

[6]

Commentary

This answer is very basic. The two points made are that 'the oven heats up … allowing more current to flow' (E2) and 'the resistance barely changes at low temperatures, leading to a very small change in voltage' (L1 and L2). There is an error in physics ('when it's cold, current will flow to the voltmeter'). This answer would score 1 mark. To improve the answer, the candidate should 'use calculations', as this is clearly specified in the question.

Question 8 – H556/03 Question 5(a)

A Level Physics A Unified Physics

5 **(a)*** **Fig. 5.1** shows a simple a.c. generator being tested by electrical engineers.

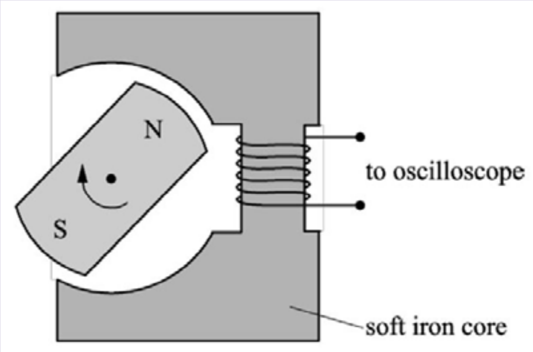

Fig. 5.1

It consists of a magnet, on the shaft of a variable speed motor, being rotated inside a cavity in a soft iron core. The output from the coil, wound on the iron core, is connected to an oscilloscope. The grid of **Fig. 5.2** shows a typical output voltage which would be displayed on the oscilloscope screen.

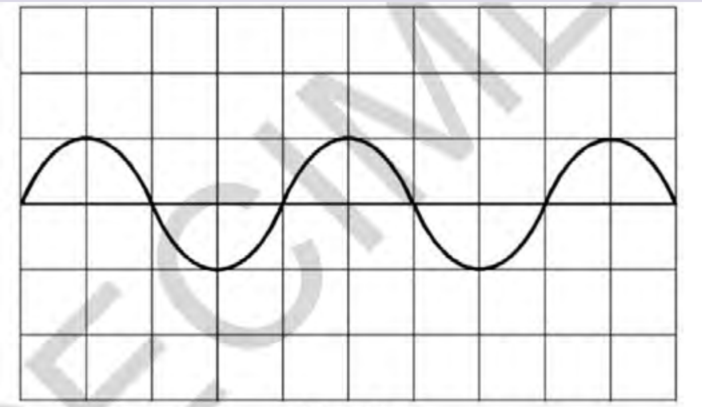

Fig. 5.2

According to Faraday's law the e.m.f. included is directly proportional to the rate of change of flux linkage. In the context of this experiment, the maximum e.m.f. induced is directly proportional to the frequency of rotation of the magnet.

Use the apparatus above to plan an experiment to validate Faraday's law of electromagnetic induction. In your description include how th edata is collected an analysed.

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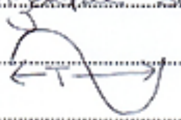
.... **[6]**

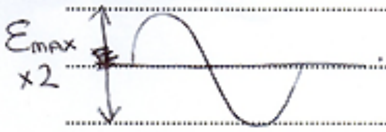
Question			Answer	Marks	Guidance
5	(a)*		**Level 3 (5–6 marks)** At least P1 and P2 M1, M2, M4 and M5 At least A2 and A3 At least C1 and C2 *This is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** At least P1 M1, M4 and M2 or M5 At least A3 At least C1 *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* **Level 1 (1–2 marks)** At least P1 At least M1 and M4 At least A3 At least C1 *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* **0 marks** No response or no response worthy of credit.	**B1 x6**	**plan P** 1. vary speed of rotation of magnet using motor control 2. expect to see amplitude of signal increase and period of waveform decrease 3. measure (maximum) e.m.f. V and period T for each setting from oscilloscope screen. **measurements M** 1. maximum e.m.f. 2. measured from peak to peak distance on graticule 3. and using V/cm scale setting 4. period rotation 5. measured along t-axis of graticule 6. and using s/cm time based setting. **analysis A** 1. record table of V.T. 2. and (calculate and record) f = 1/T 3. plot graph of V against f **conclusions C** 1. a straight line graph 2. 2 through origin 3. is required to validate Faraday's law.

Candidate1. Level 3, 5 marks

I would vary the frequency of rotation of the magnet by changing the speed of the motor. I would do this for several different values of frequency f and measure the corresponding value of maximum emf E_{max}. I would measure f and E_{max} from the scales on the axes of the oscilloscope. The horizontal scale will tell me the time period, T



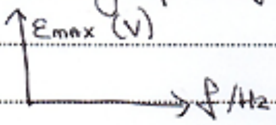
and then I can find f using the formula $f = 1/T$. The vertical scale will tell me the max emf



. I will set up a table of results like this:

E_{max} (V)	T (s)	$f = 1/T$ (Hz)

I would then plot a graph of E_{max} against f with these axes.



[6]

If Faraday's law is true then I will get a straight line through the origin because if $E_{max} \propto f$ then $E_{max} = \text{constant} \times f$

cf. $y = m x + c$

Commentary

This student has clearly achieved P1 and P3 in the 'Plan' section (P), but they have not gained P2, and so they have not met the criteria necessary for level 3. To improve their answer, they should describe how they would expect their measurements to vary as the speed of revolution increases.

In the 'Measurements' section (M), the candidate gains the level 3 criteria M1, M2, M4 and M5. However, although they mention 'the horizontal scale' and 'the vertical scale' on the oscilloscope, this is not sufficient to gain M3 or M6.

The student does very well in the 'Analysis' (A) and 'Conclusions' (C) sections, gaining full marks.

Overall, the answer is long and detailed, and has clear structure. The information is supported with relevant diagrams. The response is clearly in level 3 overall, but would probably gain only 5 marks since not all the level 3 criteria have been met.

Candidate 2. Level 2, 4 marks

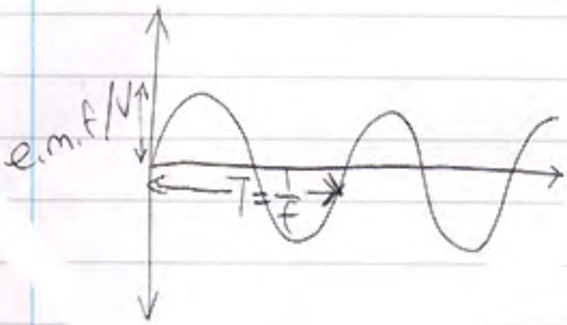
Keeping all variable constant apart from the speed of revolution of the magnet. For each speed, measure the maximum magnitude of e.m.f induced for each speed using an oscilloscope.

~~fore~~

50 revs^{-1} → $\frac{1}{50}$ s per rev → 50 Hz

Once collected these data plot a graph with max e.m.f on y-axis and frequency on x-axis and it should produce a straight through origin graph hence $E \propto f$.

<u>Measurements</u>



Commentary

This student has made an attempt at P1 in the 'Plan' section (P), although they have not said how the speed of revolution could be varied, and they have achieved P3 since their graph indicates the measurements they will take 'for each speed'. However, they have not gained P2, and so they have not met the criteria necessary for level 3. To improve their answer, they should describe how they would expect their measurements to vary as the speed of revolution increases.

In the 'Measurements' section (M), they gain M1, M4 and M5 (again from the graph), which characterises a level 2 response. To improve their answer to level 3, they should measure the maximum emf using the peak-to-peak distance.

The student gains A3 only in the 'Analysis' section (A), although the candidate seems to be making an attempt at A2 with their demonstration that T = 1/50s leads to f = 50Hz. This is a high level 2 response, but they would have to clarify how f is calculated in order to reach level 3.

The candidate does well in the 'Conclusions' section (C) (it is clear what they mean by 'a straight through origin graph') and here they reach level 3.

Overall, the answer is quite basic, but the information is supported by some evidence (in the form of a graph). There is a line of reasoning presented with the structure 'What to do – what to measure – what to plot – what to expect'. This answer is in level 2 overall and would score 4 marks.

Candidate 3. Level 1, 1 mark

Increase the speed of the rotation to increase the frequency. Record the value of the max e.m.f produced from the varied frequency of rotation. Plot on a graph of e.m.f vs frequency to show there is a positive linear correlation between the increasing frequency and induced e.m.f. This shows that the induced e.m.f $\propto$ frequency

For each frequency

Commentary

The information in this response is poorly supported. For example, the student has told us to 'Record the value of the max emf' but has not told us how to do so. Similarly, they have told us to 'Increase the speed of the rotation' but has not said how this could be achieved. This means that they have attempted P1 and P3 in the 'Plan' section (P) but not fully achieved them, which puts their response in level 1.

In the 'Measurements' section (M), the candidate has gained M1 only, which means that they have not even met the criteria necessary for level 1. To improve their answer, they should describe how to measure the period of rotation T using the scales on the oscilloscope.

The candidate gains A3 only in the 'Analysis' section (A), which is a level 1 response, and C1 in the 'Conclusions' section (C) together with an attempt at C3, which is a low level 2 response.

However, given that level 1 has not been achieved in the M section and that the response is extremely short and basic, this answer can only score 1 or 2 marks.

Question 9 - H557/01 Question 38 (b)

Here are two correct statements:

- Radioactive decay is a random process
- The decay curve of a radioisotope can be predicted mathematically.

Use your understanding of the decay constant to explain how both statements can be true for sources containing large numbers of atoms. Explain how you expect the scatter of the results shown in **Fig. 38.1** to change as the count rate falls.

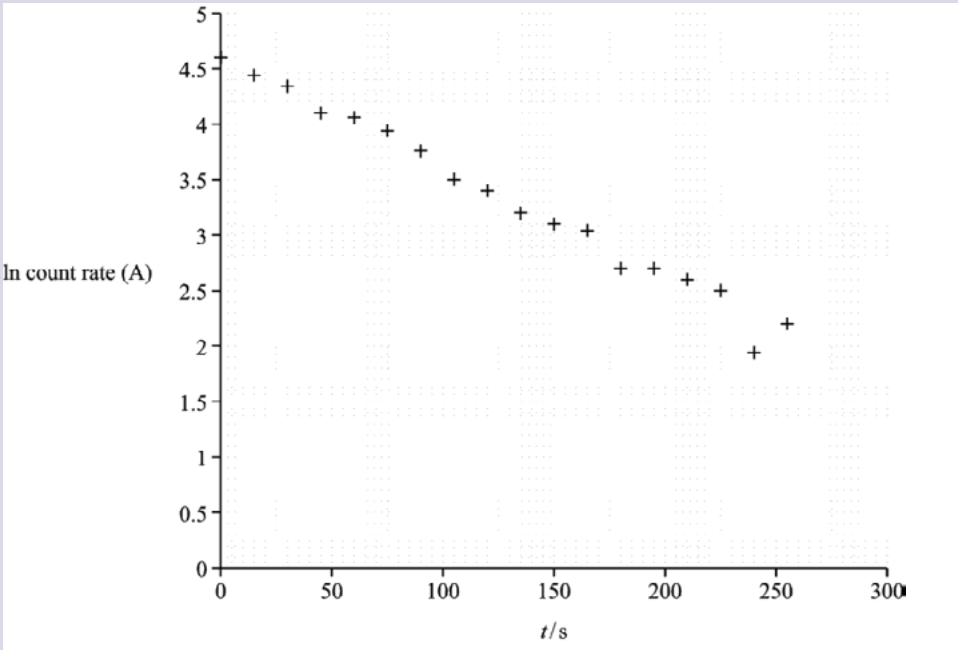


Fig. 38.1

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<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>38</td><td>b</td><td></td><td>Level 3 (5–6 marks)
Marshals argument in a clear manner and includes clear explanation of three strands:

• randomness
• the exponential curve as a model
• the effect of the number of nuclei present

There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.

Level 2 (3–4 marks)
Shows clear understanding of at least two of the three strands above to the argument
or
covers all three at a superficial manner and does not include enough indicative points for level 3.

There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.

Level 1 (1–2 marks)
Makes at least two independent points that are relevant to the argument but does not link them together and shows only superficial engagement with the argument.

The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.

0 marks
No response or no response worthy of credit.</td><td>6</td><td>Indicative scientific points may include:
Randomness
• cannot know when an individual nucleus will decay
• explanation of the meaning of the decay constant (e.g. probability of decay of individual nucleus in unit time)
• λ as the probability related to dN/dt
• discussion of an analogue (e.g. coins or dice)

The exponential curve as a model
• reference in correct context to $N = N_0e^{-\lambda t}$
or
• linking to $dN/dt = -\lambda t$

The effect of the number of nuclei present
• for fixed λ the number of nuclei decaying in a given time can be predicted given sufficiently large sample
• as count rate falls, the number of nuclei that may decay also falls
• as the number of nuclei falls the variation from the predicted outcome will increase
• with increase variation comes increasing scatter</td></tr>
</table>

Candidate response 1. Level 3, 5 marks

Whether a nucleus decays or not is a random process, not affected by heat or chemical change. This means that it is not possible to predict when a decay will occur, but given sufficient time and a large enough sample you can predict what proportion of a sample may have decayed. In a given unit of time, a nucleus has a probability that it will decay, this is the decay constant, λ. Another way of putting this is that in a given time a sample of a large size will decay and the proportion that decays will be the probability of a nucleus decay. This creates an exponential decay meaning over the same given time period, the sample will decay by the same fraction. The equation $N = N_0e^{-\lambda t}$ can be used to show this. If this sample is too small then the the number of nuclei decaying is also going to be small and will also be more variable and may not show a strong pattern.

Commentary

This candidate explains the random nature of decay well and discusses the impact of the number of nuclei present. The brief explanation with the equation stated means that this falls into the Level 3.

What the candidate did well

Explanation of the random nature of decay is done well and the definition of λ, along with the modelling idea is explained effectively.

How the answer could be improved

Explaining the stated equation fully would be beneficial.

Candidate response 2. Level 2, 3 marks

The decay of a nucleus of an atom is random, like throwing a dice, you can't predict the outcome. The probability of decay can be modelled using an exponential model, and as the number of nuclei decreases, the number of nuclei available to decay is lower. The model is less effective at a smaller sample size.

Commentary

They three strands are discussed in a superficial manner and does not include sufficient detail in explanation for enter the level 3 band.

How the answer could be improved

The discussion on randomness is vague and should make reference to the individual nuclei. Reference to the exponential relationship with explanation would improve this answer.

Candidate response 3. Level 1, 1 mark

Even though decay is a random process, the average decay of a radioactive substance gives the decay constant of a materials which can be used to mathematically model the decay of an isotope. As the count rate falls, the correlation shown on the scatter graph will become weaker and the placement of the plotted points on the graph will become more random. This is because for a cage sample the decay constant relating to the average holds true but for a small sample there are less isotopes with the average decay rate and so the random natur is more apparent.

Commentary

The candidate discusses the idea of decay and how the decay constant is used, by repeating the correct statements given in the question. No credit can be given for this. Discussion into the effect of the number of nuclei present is attempted, albeit not completely. Credit can be given for noting of the variation in results as the count rate falls as shown in the graph.

How the answer could be improved

The candidate should explain what the random process means in this context, defining what λ is, and how it relates to the exponential curve model. This last point could be done simply with careful use of the data and formulae booklet. Further explanation into the reason for the increased scatted should be given.

Question 10 - H557/02 Question 5 (c)

(c)* Measuring the period of oscillation of a floating rod is one way of determining the acceleration of gravity but it is not as popular as using a simple pendulum.

Suggest and explain reasons why the pendulum method is likely to be chosen if a value of g with a small uncertainty is wanted.

In your answer you may wish to consider a pendulum of length 1m and a rod of mass 1 kg and cross sectional area 0.005 m^2 floating in water of density 1000 kg m^{-3}.

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<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>5</td><td>(c)*</td><td></td><td>Level 3 (5–6 marks)
Both methods compared and advantages of SP and disadvantages of FR identified. Qualitative comparison of uncertainties of the different methods made, even if not completely successful, linking to value for g.

There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.

Level 2 (3–4 marks)
Compares both methods and identifies some advantages of SP method. Partial attempt to quantify differences.

There is a line of reasoning presented with some structure. Theinformation presented is in the most-part relevant and supported by some evidence.

Level 1 (1–2 marks)
Makes direct comparison between at least one shortcoming of FR method and an advantage of SP method. No attempt to quantify uncertainty.

The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.

0 marks
No response or no response worthy of credit.</td><td>6</td><td>Indicative scientific points may include:

floating rod method

• Method is indirect
• Rod may oscillate in different directions
• Damping will stop oscillations
• Difficult to time a large number of oscillations to reduce ΔT
• Water surface will move making it hard to judge position of rod
• Use of the formula in the form $g = \frac{4\pi^2 m}{T^2 \rho_w A}$
• Percentage uncertainty in m and A are small compared with T
• T will be of the order of 1 s
• $\Delta T/T$ significantly larger than for pendulum
• logical argument linking uncertainties in measurement through to value of g

simple pendulum method

• Method is indirect
• Can time a large number of oscillations to reduce ΔT
• May be systematic error in measuring L
• Use of dense bob and light, flexible thread minimises frictional losses
• Easy to judge position of bob e.g. passing though centre
• Use of the formula in the form $g = \frac{4\pi^2 l}{T^2}$
• • T will be of the order of 2s
• • $\Delta T/T$ significantly smaller than for floating rod
• • logical argument linking uncertainties in measurement through to value of g</td></tr>
</table>

Candidate response 1. Level 3, 6 marks

With the pendulum bob method you are dealing with less measurements, $T = 2\pi\sqrt{\frac{L}{g}}$, so if

the length is set at 1m then you're taking measurements of time only, which should work out at around T = 2 s. You can take a measurement for multiple swings (which is fairly easy to do, using the bottom of the swing as a marker) and find an average time period, reducing the uncertainty in the time measurement significantly. To help reduce the uncertainty in this method you can increase the L measurement to reduce %uncertainty and try to use a material that is really smooth so friction is less of an issue.

In comparison the floating rod method will require you to take more measurements $T = 2\pi\sqrt{\frac{m}{gA\rho_w}}$

so you need to know/find out/measure m, ρ and A as well as T. The more measurements you have to take, the more uncertainties you need to deal with. The measurement of T for the rod would be around T= 0.9 s, and would be difficult to measure as the rod may not oscillate in a uniform way (it will probably topple over, and the water will move too), and timing for multiple oscillations would be difficult as the water would damp the oscillation greatly, meaning that you cannot reduce the error by taking multiples and finding an average. The T measurement will have the greatest uncertainty as a result (much bigger than m, ρ and A), and will certainly be greater than for the simple pendulum method.

Commentary

The candidate compares both methods, outlining advantages and disadvantages with reference to uncertainty. The data is used, although not fully utilised.

What the candidate did well

The candidate identifies the formulae and the measurements needed, and presents the problems in the collection for this data for each method in a qualitative and quantitative manner.

How the answer could be improved

The candidate could compare the values for T calculated. Overall this was a higher band response, which addressed the main concepts in an organised manner.

Candidate response 2. Level 2, 3 marks

Using the data:

$T = 2\pi\sqrt{\frac{1}{1000\times9.81\times0.005}}$ = 0.897 s. Which is a really small time period for a single oscillation of the rod, especially as I can only measure to about 0.5 s (on a good day), and the rod is going to bob about 'imperfectly', so you can't even take multiple bobs and then find an average, in the way you would easily do for a simple pendulum. Also you're taking lots more measurements for the floating rod method which will increase your uncertainty.

Commentary

The candidate presents an argument that is not fully explained but meets a number of the key scientific points. It is pleasing to see the candidate use the data to support their arguments, but they failed to compare the two methods fully and as a result they have not accessed the highest band.

What the candidate did well

The candidate uses the data to qualify their argument on data collection and identifies the key disadvantages for one method.

How the answer could be improved

The candidate could present their reasoning in a clearer and more logical manner. They should ensure that they explain the advantages of the simple pendulum method, as they have simply implied this.

Candidate response 3. Level 1, 2 marks

The rod could bob left to right so your T value would be hard to take, and give you poor repeats. The pendulum swing is easy to measure T and you can take multiple swings simply. So the pendulum method would be better.

Commentary

The candidate compares one shortcoming of the floating bob method and the advantage of the simple pendulum on this variable. The lack of explanation means this is a lower band answer

What the candidate did well

The candidate identifies the key shortcoming of the floating bob method and the advantage of the simple pendulum on this variable, particularly with repeats.

How the answer could be improved

The candidate could use the data given in the question and consider other factors that impact the uncertainty with the different methods.

Question 11 – H557/03 Question 3 (a)

Fig. 3.1 shows a short bar magnet being dropped vertically through a small horizontal coil.

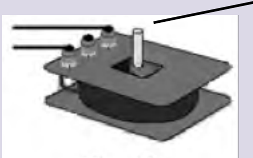
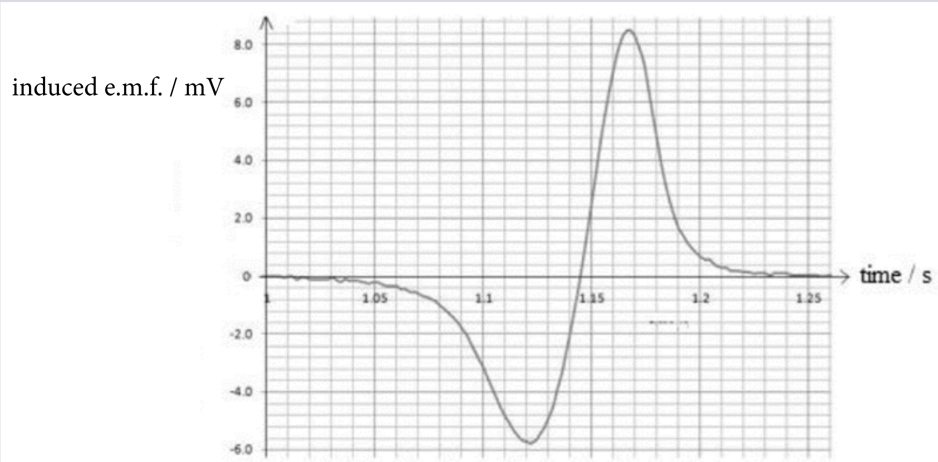


Fig. 3.1

Fig. 3.2 shows the graph of how the e.m.f. induced in the coil varies with time, as the magnet passes through the coil.



(a)* Identify and explain the main featires of the peaks of induced emf shown on **Fig. 3.2**, in terms of Faraday's law of electromagnetic induction.

[6]

Question			Answer	Marks	Guidance
3	(a)*		**Level 3 (5–6 marks)** All 3 features fully explained: sense and amplitude explained in terms of changes of flux linking coil. Explanations involve reference to Faraday's Law or $\varepsilon = (-) N\Delta\Phi/\Delta t$. **Sense:** increase in $N\Delta\Phi$ is + ve and decrease – ve. **Amplitude:** peak occurs when rate of change of flux linkage is greatest, may be mathematically expressed. **Area:** equated to total change of flux linkage with coil = $\Sigma\, \varepsilon\, \Delta t = (-) N\Delta\Phi$ **or** sum of strips and same flux links coil on way in as unlinks from coil on way out. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** 2 or 3 features quite well explained: sense and amplitude explained in terms of changes of flux through coil. Explanation may involve reference to Faraday's Law or $\varepsilon = (-) N\Delta\Phi/\Delta t$. Area simply equated to change of flux and idea that increase = decrease in flux **or** both end points have zero flux through coil. *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* **Level 1 (1–2 marks)** 1 or 2 features explained at a low level in terms of cutting lines of magnetic field e.g. cut in opposite direction, cut at a different rate, total field cut on way in equals field cut on way out. Some attempt at $\Delta B/\Delta t$. *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* **0 marks** No response or no response worthy of credit.	6	**Indicative scientific points may include:** **Features of induced peaks to be explained** • Sense of each peak opposite • Amplitude of 2nd peak larger because greater speed or greater (-) $N\Delta\Phi/\Delta t$ • area under peaks is equal because $\Sigma\, \varepsilon\, \Delta t = (-) N\, \Delta\Phi$ **Vocabulary guidelines** • Level 3 in terms of changing flux linkage $N\Phi$ with coil • Level 2 in terms of changes of flux Φ through coil • Level 1 in terms of field lines B being cut by coil **Marking guidelines** • **accept** arguments using mathematical symbolism

Candidate response 1. Level 3, 6 marks

As the magnet falls through the coil it induces an emf in the coil of wire. Faraday's law states that the emf = rate of change of flux linkage, where the flux linkage = number of turns on the coil x magnetic flux. In this case the number of turns on the coil remains constant.
Features on the graph: An increase in the emf induced (negative direction), followed by an increase in the emf in the positive direction. The positive emf is greater than the negative emf.
The increase in the induced emf in the negative direction is due to the increase in the rate of change of flux linkage as the magnet enters the coil, this increases and is a maximum at the peak, then reduces until the magnet is within the coil, as it leaves the coil the magnet it is moving away from the coil (rather than towards) and so the emf is induces in the opposite direction, and the amount of flux linkage increases again as the poles have more flux. As it is falling the magnet will be accelerating, and so the rate of change of flux will increase as it leaves the coil hence the higher induced emf. As the number of turns stays constant and the amount of flux stays the same, then the emf x time is a constant according to Faraday's law, so the area under both the positive and negative peaks should be equal.

Commentary

This is a higher band answer, with clear arguments that link Faraday's law to the features identified on the graph correctly and effectively. All essential vocabulary is used correctly.

What the candidate did well

The candidate outlines the key features of the graph and explains them using Faraday's law confidently. The answer is well structured and the information is relevant.

Candidate response 2. Level 2, 3 marks

Around the magnet is a magnetic field represented by lines of flux. When there is movement between a magnetic field and a wire, it can induce a current. As the magnet falls through the coil of wire an emf is induced across the coil. As the magnet enters the coil the amount of flux linkage increases and hence due to Faraday's law (emf = the rate of change of flux linkage) an emf is induced. It increases until the magnet is fully inside the coil and then as it leaves it induces an emf in the opposite direction. This is probably due to it being pulled back out of the coil. I'd say it is pulled out at a faster rate as the peak is larger than the trough.

Commentary

The candidate uses the key terms; flux and flux linkage correctly. Faraday's law is mentioned and then ideas from this are used to justify a feature of the graph at the end, but this is not linked explicitly. Other features of the graph are noted; direction of the induced emf, but the understanding of the situation is not complete. The lack of direct explanation with reference to Faraday's law and its variables mean it cannot be a Level 3 response, but the candidate does explain features of the graph with reference to flux linkage and rate, meaning that it is a level 2 response.

What the candidate did well

The candidate states Faraday's law and uses key terms well.

How this answer could be improved

To improve this response the candidate needs to utilise Faraday's law to explain all the features fully. They should ensure that they explain when the flux linkage is increasing, decreasing and when it is at is maximum and how this is shown in the graph. Comments on the area under the peaks would be expected for a higher level response.

Candidate response 3. Level 1, 2 marks

As the magnet falls the magnetic field cuts through the lines of flux. This induces an emf in the coil of wire that it is falling through. One of the peaks is positive and the other is negative, due to the different ends of the magnet field cutting the coil.

Commentary

The candidate has identified a feature from the graph, that the peaks are in opposite directions on the graph, with limited explanation. The explanation as to what is happening is basic and lacks the detail required for a higher level answer. The omission of reference to Faraday's law places this securely in the level 1 band, despite the use of the term flux.

How the answer could be improved

The candidate should explain what is happening with reference to Faraday's law of electromagnetic induction, given in the formulae booklet. Discussion relating the rate of change of flux linkage to what is seen in the graph would push this into the higher band.

Question 12 – H557/03 Question 4 (a) (iii)

(iii) The student calculated the total amount of charge to flow from the capacitor in the first 30 seconds. She used two methods:

Method 1 – using the relationship $\Delta Q = C\,\Delta V$

Method 2 – using $I = \frac{V}{R}$ and the area under the $I\,(t)$ graph where R is 5.0 kΩ

Show how the total charge flow may be calculated in both cases and comment on how the two methods compare.

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Question			Answer	Marks	Guidance
4	(a)*	(iii)	**Level 3 (5–6 marks)** Performs both calculations correctly and appreciates the strengths and limitations of both. Principally: for Method 1 relies on $Q \propto V$ which is valid; for Method 2 the y-axis needs to be re-interpreted and the area being measured (integration by counting squares) gives an approximate estimated answer. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Performs both calculations successfully but method may not be completely clear **or** does not compare them sufficiently well. *There is a line of reasoning presented with some structure. The information presented is in the most-part relevant and supported by some evidence.* **Level 1 (1–2 marks)** Attempts one or both calculations but does not successfully compare the two methods. *The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.* **0 marks** No response or no response worthy of credit.	6	**expected comparison of two methods** • method 1 does not depend on the time variation of V(t), only on the accuracy of start and end p.d.s. and the R and C values. It is a calculation based on theory. • method 2 depends on counting squares and fractions of squares under the exponential decay curve which is an approximation to the area under the graph leading to an estimate of the charge flow. **points worthy of credit :** • method 1 calculation: $\Delta Q = C\Delta V$ with $\Delta V = (6 - 1.8)$ V • gives 19.7 mC • method 2 estimation: re-scaling of y-axis to represent current • area under I (t) represents $\Delta Q = I\,\Delta t = V\Delta t/R$ • each 1 cm square 1 x 10/5000 = 2 mC • between 0 and 30 s there are about 10 squares • so total charge flow = 10 x 2.0 x 10^{-3} = 20 mC accept answers in range 18 to 22 mC

Candidate response 1. Level 3, 5 marks

The potential difference decreases by 4.2V (from 6V to 1.8V) over 30 seconds.
Using method 1: $\Delta Q = C\Delta V$, where $C = 4700\mu F$
$\Delta Q = (4700 \times 10^{-6}) \times (6 \times 1.8)$
$\Delta Q = 0.0197C = 19.7mC$
This is a direct calculation and does not take into account the fact that there is variation in the measurements over time. It requires two sets of measurements taken to be accurate, and the assumption that the given values are good.

Method 2: The area under the curve = Vt. Q=It and I=V/R, $\Delta Q = (Vt)/R$, where R = 5.0 kΩ
Q = Area under the curve / 5000

Area = triangle + rectangle
= 0.5(30 x 4.2) + (30 x 1.8)
= 63 + 54 = 117 Vs
Q = 117/5000 = 0.0234 C = 23mC.
This method is going to give an overestimation as the triangle I have used is over the line of the graph, so it's probably a bit less that the value I have got. I could have counted each square and partial square to get a better approximation.

Commentary

The candidate has performed both methods of calculation and has commented on the methods individually. Despite the candidate not achieving an acceptable answer within the range given in the mark scheme, they have recognised that their answer is an over estimate. This demonstrates a good understanding of the method which has been carried out correctly overall.

What the candidate did well

The candidate has outlined their reasoning well and performed the calculations confidently with justification.

How this answer could be improved

Performing method 2 to a greater degree of accuracy as noted by the candidate, to achieve a value within the accepted tolerance.

Candidate response 2. Level 3, 4 marks

$\Delta Q = C \Delta V$

$\Delta Q = 4700 \times 10^{-6} F \times (6V - 1.8V)$

$= 0.01974 C$

Area under Curve $= 106$ VS

$I = \frac{V}{R}$ $\frac{106 \text{ VS}}{5000 \Omega}$

$= 0.0212$ AS

$= 0.0212$ C

The area under the Curve is an overestimate of the actual value

Method 1 Suggests a Liner discharge which is also an over estimate

Commentary

The candidate performs both calculations correctly and clearly in a logical format. The comparison of the methods made is limited and could be improved. This puts the response in the level 2 band.

What the candidate did well

The candidate has performed the calculations correctly, and has made an attempt to comment on the methods.

How the response could be improved

The calculations could be clearer and the comparison of the two methods could be more specific.

Candidate response 3. Level 1, 1 mark

<u>Method 1</u>
From the graph the V decreases from 6 to 1.8V over 30 seconds.
Q = CV and C = 4700μF
Q = (4700 x 10^{-6}) x (6 x 1.8)
Q = 0.01974 C

<u>Method 2</u>
Area under the curve
(30s x 1.8) + (30 x 4.2) = 54 + 100 = 154 Vs   I = V/R.   R=5kΩ = 5000Ω

Commentary

The candidate has completed the calculation using method 1 and has made an incomplete and inaccurate attempt to use method 2. No comparison of the method was made and so this is a level 1 response.

How this answer could be improved

The candidate has not calculated the area under the curve correctly and has also failed to see the relevance of finding the area under the graph given as they have not utilised this information with the other data and formula given. The second half of the question has not been attempted.

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