Examiners' Report
January 2012

GCE Physics 6PH02 01

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Introduction

While building on GCSE Physics, the unit includes a number of quite new areas, particularly in relation to Quantum Physics, and this paper allowed students to show good progression.

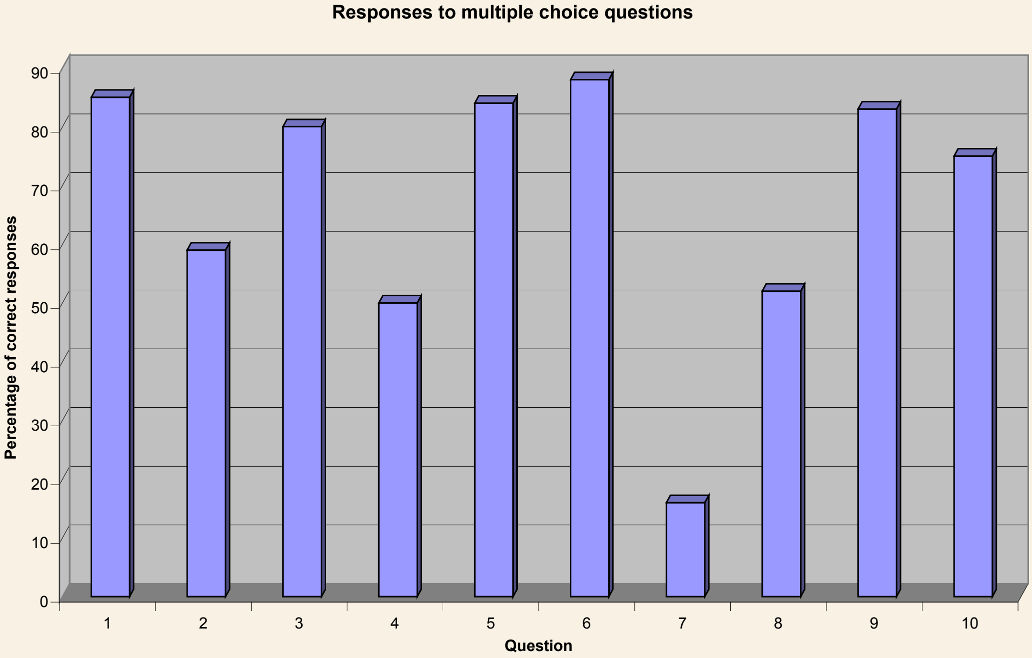
Performance was often better in parts of questions requiring calculation than those requiring descriptions. There were few unit errors seen in numerical responses.

Better responses might have been expected to a number of questions involving standard phenomena in relatively straightforward contexts, e.g. atomic spectra, photoelectric effect and standing waves. Apart from a few context-specific points in particular questions, the mark schemes for these have the same general points and they can easily be learned as ‘set pieces’.

There was evidence of a fair bit of confusion between the production of atomic spectra and the photoelectric effect and also the relatively common misconception that resistance is found using the gradient of potential difference vs current graphs. In addition, had the historical importance of the work on quanta of Planck and Einstein been stressed in the teaching as suggested by specification point 71, it is unlikely that so many students would have missed the relevance of photons to the photoelectric effect.

Section A

Question	Percentage of correct responses	Most common alternative
1	85	A
2	59	B
3	80	D
4	50	B,C
5	84	B
6	88	C,D
7	16	B
8	52	C
9	83	A
10	75	C



Large majorities responded correctly to questions 6, 1, 5, 9 and 3. Question 10 had a very good response rate as well and 2, 9 and 4 were fair. Very few answered q 7 correctly. The preferred incorrect responses to some of the questions give some idea of misconceptions.

1. Students getting this wrong and choosing A just had the spectrum in reverse order.

2. Those choosing B at least knew that a lower frequency corresponded to a longer wavelength. It is worth noting that those with higher marks for the paper tended to have a preferred incorrect choice of C, so they at least connected it with the relative motion of the star to the observer.

7. Although the overall preferred incorrect choice was B, at the lower end of the ability range C was chosen much more often. This suggests that those students just remembered the shape of the V-I graph they knew and selected this without regard to the axes while the more able at least realised that a greater resistance resulted in a lower current, even if they could not select the correct inverse relationship.

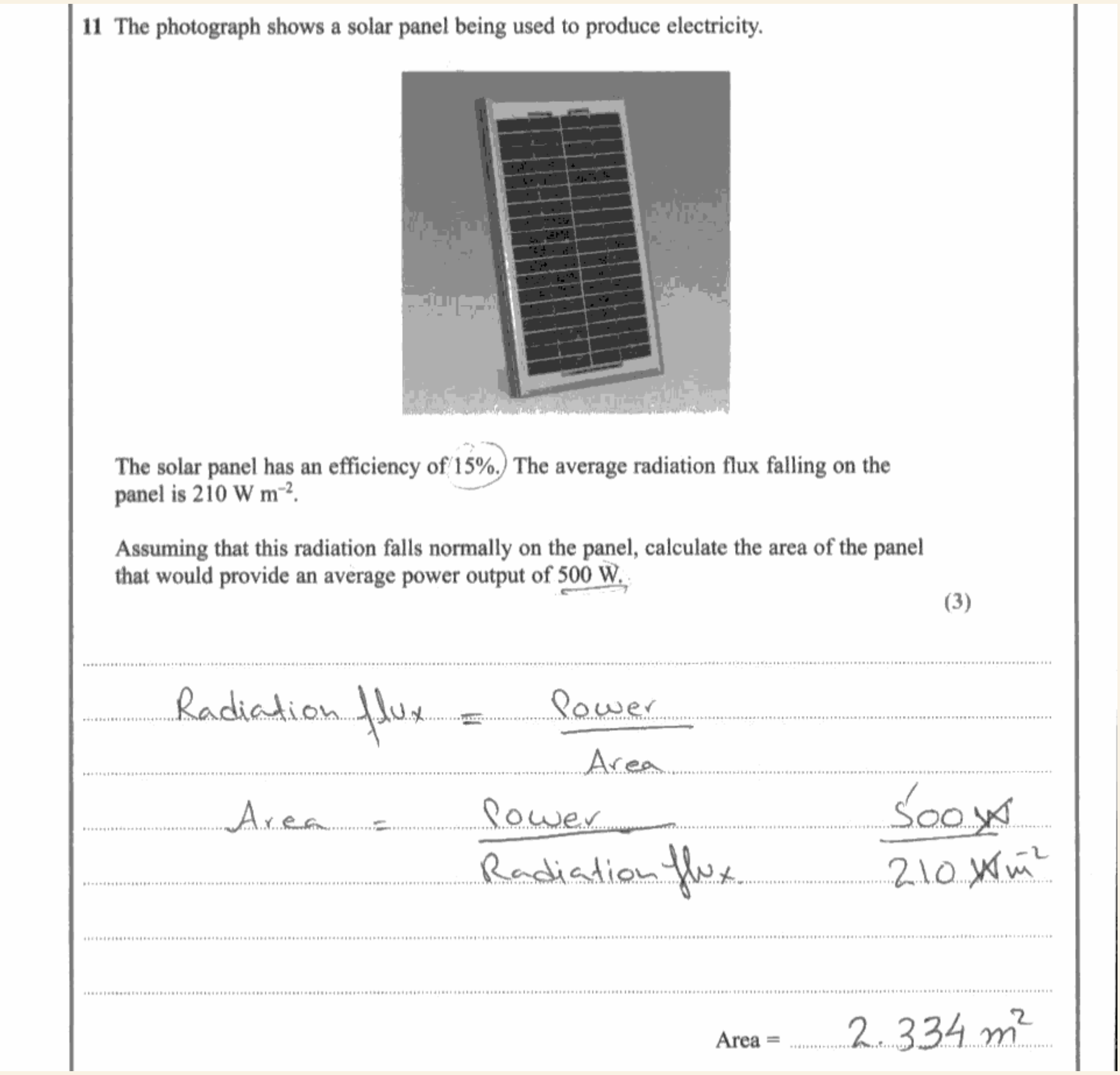
8. Here the main error was in neglecting to allow for the time ‘there and back’ rather than a problem with ms as a unit.

9. The slight confusion some have with the wave phenomena ending in ‘fraction’ was also seen in question 12 where some suggested sound from the tiger would reach people through the hill after being refracted on its entrance.

10. The choice of C reflected some awareness, if somewhat vague, that energy and time are involved in power.

Question 11

Just over half of the candidates completed this question successfully, most commonly starting by applying the 15% efficiency to the incident flux. The majority of those not awarded full marks could apply area = power / radiation flux but ignored the 15% entirely to get an answer of 2.4 m^2, or applied the efficiency incorrectly by finding 15% of 500 W, to give an answer of 0.36 m^2. One might have hoped that the latter answer would stand out as incorrect by simple consideration of the values given, since 500 is clearly more than double 210, suggesting that not all candidates considered the detail of this application before attempting their answers.



11 The photograph shows a solar panel being used to produce electricity.

The solar panel has an efficiency of 15%. The average radiation flux falling on the panel is 210 W m^{-2}.

Assuming that this radiation falls normally on the panel, calculate the area of the panel that would provide an average power output of 500 W.

(3)

$$\text{Radiation flux} = \frac{\text{Power}}{\text{Area}}$$

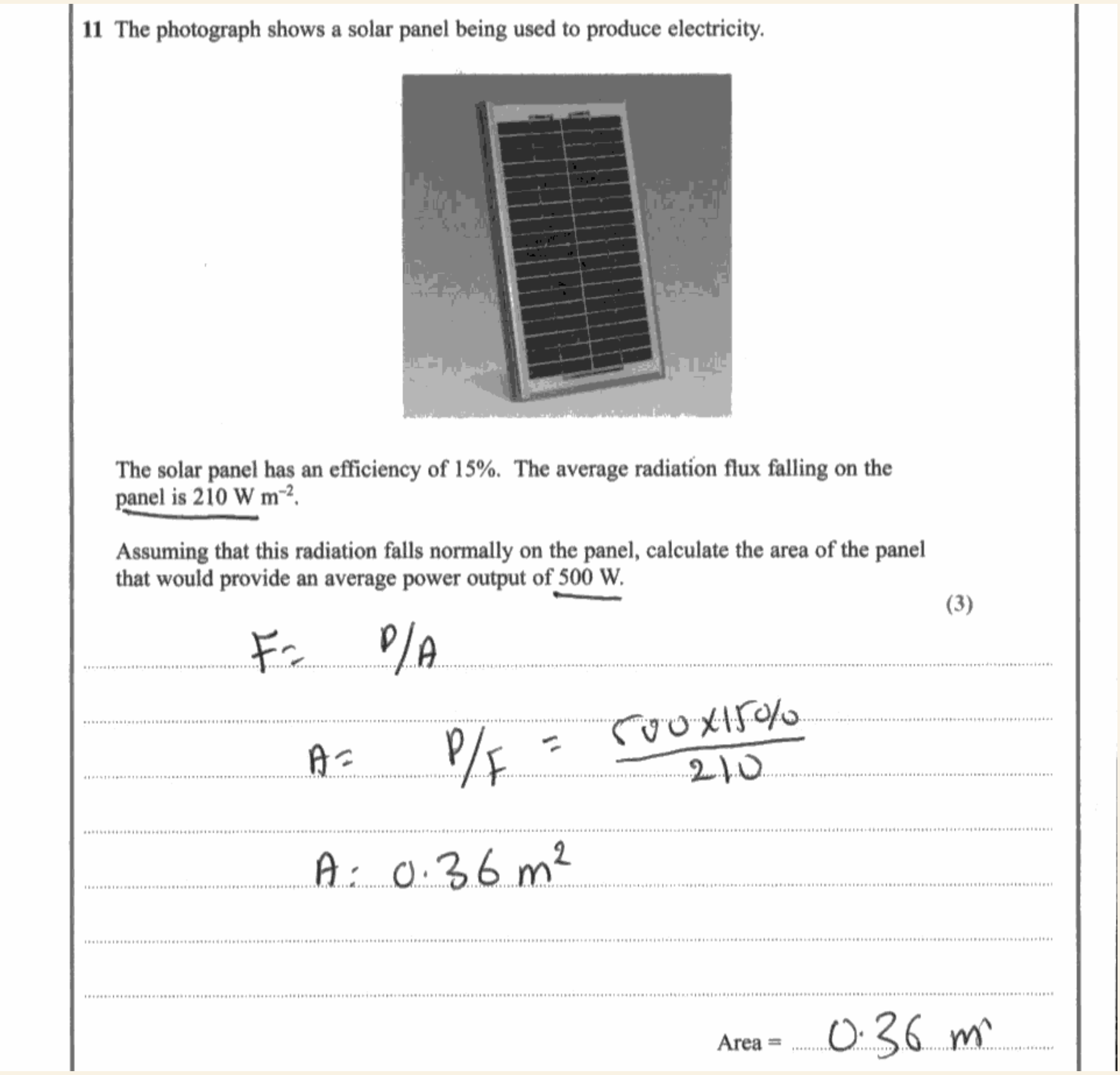
$$\text{Area} = \frac{\text{Power}}{\text{Radiation flux}} \qquad \frac{500\,W}{210\,W\,m^{-2}}$$

Area = 2.334 m^2

ResultsPlus

Examiner Comments

This candidate has used Power/Radiation flux, and has even included units to confirm that the quantities are being applied correctly, but, despite circling 15% on the script, has not used the efficiency.



11 The photograph shows a solar panel being used to produce electricity.

The solar panel has an efficiency of 15%. The average radiation flux falling on the panel is 210 W m^{-2}.

Assuming that this radiation falls normally on the panel, calculate the area of the panel that would provide an average power output of 500 W.

(3)

$F = P/A$

$A = P/F = \frac{500 \times 15\%}{210}$

$A = 0.36\ m^2$

Area = $0.36\ m^2$

ResultsPlus

Examiner Comments

Power/Flux has again been used, but the efficiency has been applied to find a percentage of the output rather than the input. As the maximum possible power for unit area is 210 W a candidate might be expected to notice that a lesser area could not possibly provide 500 W.

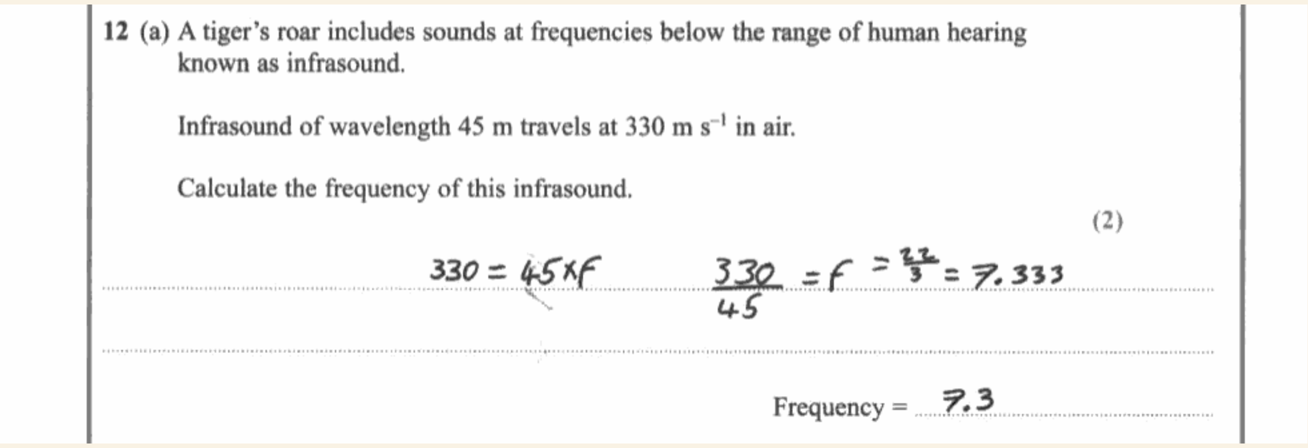
ResultsPlus

Examiner Tip

Check that the results of calculations make sense in the given context.

Question 12a

This presented few difficulties with the great majority gaining both marks. A few used units of s^{-1} instead of Hz, which was accepted, and some gave the fractional answer 22/3, which was not accepted.



12 (a) A tiger's roar includes sounds at frequencies below the range of human hearing known as infrasound.

Infrasound of wavelength 45 m travels at 330 m s^{-1} in air.

Calculate the frequency of this infrasound.

(2)

$330 = 45 \times f \qquad \frac{330}{45} = f = \frac{22}{3} = 7.333$

Frequency = 7.3

ResultsPlus

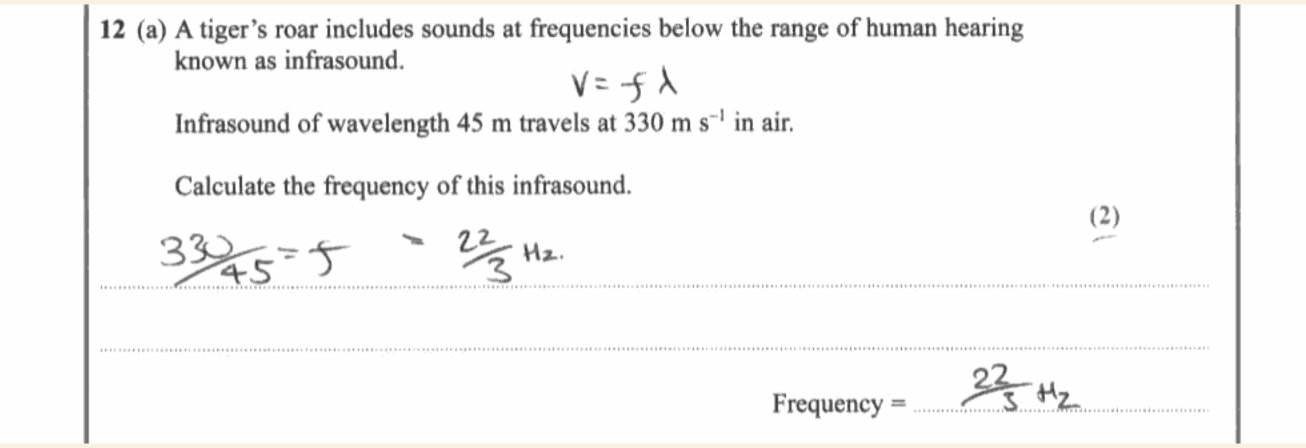
Examiner Comments

The calculation has been completed correctly but the answer has been given without the unit so the final mark has not been awarded.

ResultsPlus

Examiner Tip

Quantities must have a magnitude and a unit. Make sure you include the unit or you will not be given the final mark for the answer.



12 (a) A tiger's roar includes sounds at frequencies below the range of human hearing known as infrasound.

$V = f\lambda$

Infrasound of wavelength 45 m travels at 330 m s^{-1} in air.

Calculate the frequency of this infrasound.

(2)

$330/45 = f = \frac{22}{3}$ Hz.

Frequency = $\frac{22}{3}$ Hz

ResultsPlus

Examiner Comments

The quantities have been used correctly, but the final answer has been quoted in fraction form so only the first mark has been awarded.

ResultsPlus

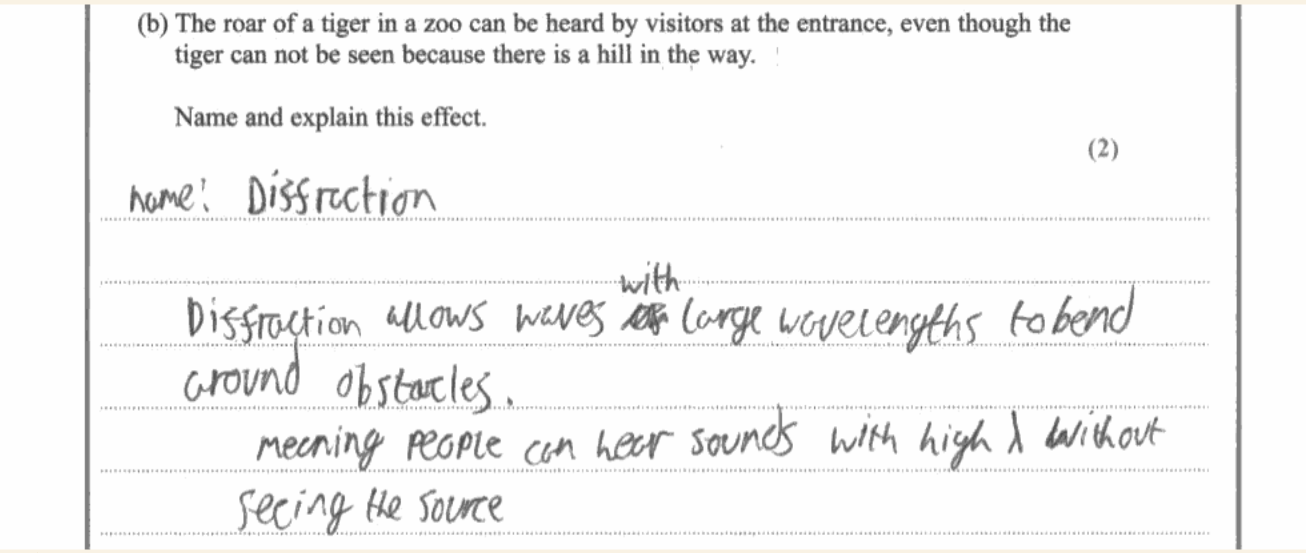
Examiner Tip

Some calculator displays default to fractions. Candidates should remember the appropriate procedure to give a decimal output.

Question 12b

Three quarters of the entry were able to identify diffraction correctly, with incorrect suggestions including refraction, reflection, the Doppler effect and occasionally 'defraction', too close to 'refraction' to be acceptable. The examiners thought Doppler effect may have been suggested to some candidates by the use of 'effect' in the question.

Slightly under half of those giving diffraction went on to explain the effect correctly in the given context, with only a minority including a diagram. It was common to see references to waves 'bending' rather than 'spreading'. Many candidates only understood diffraction in terms of a gap specifically rather than diffraction at an edge and gave descriptions of waves passing through a gap in the hill, often citing the wavelength as matching this gap.



(b) The roar of a tiger in a zoo can be heard by visitors at the entrance, even though the tiger can not be seen because there is a hill in the way.

Name and explain this effect.

(2)

name: Diffraction

Diffraction allows waves ~~of~~ with large wavelengths to bend around obstacles.

meaning people can hear sounds with high λ without seeing the source

ResultsPlus

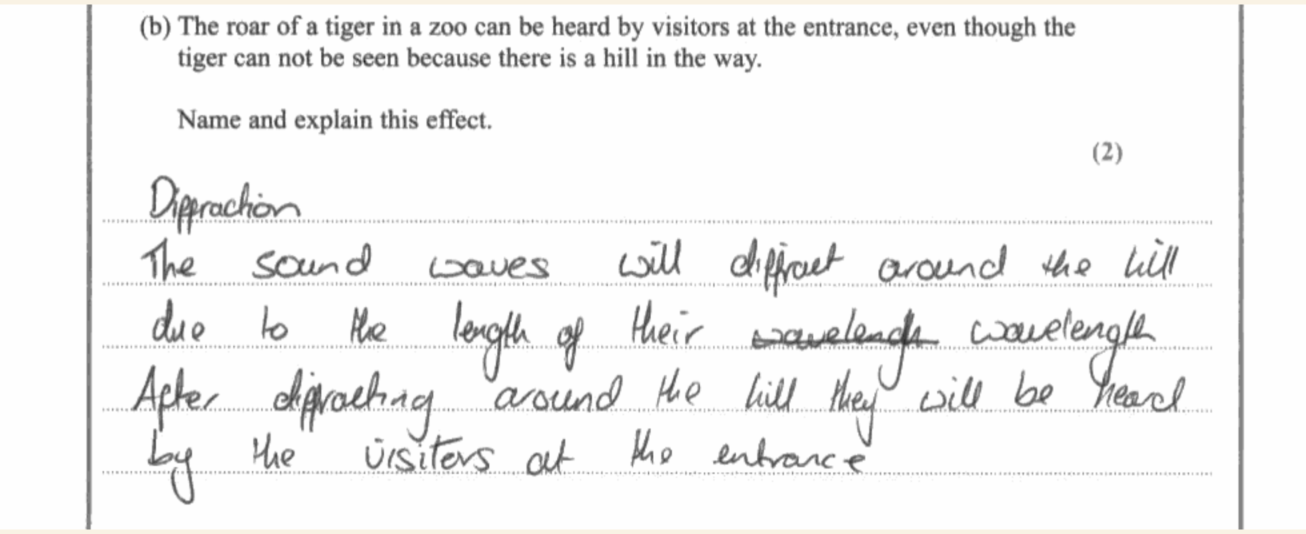
Examiner Comments

The effect has been correctly identified as diffraction but the explanation refers to bending of waves rather than spreading out. High wavelength has been mentioned, but its relevance has not been stated.

ResultsPlus

Examiner Tip

Be sure to learn the standard definitions of the terms listed in the specification.



(b) The roar of a tiger in a zoo can be heard by visitors at the entrance, even though the tiger can not be seen because there is a hill in the way.

Name and explain this effect.

(2)

Diffraction

The sound waves will diffract around the hill due to the length of their ~~wavelength~~ wavelength After diffracting around the hill they will be heard by the visitors at the entrance

ResultsPlus

Examiner Comments

Diffraction has been identified, but the term has effectively been repeated in the explanation where it says 'diffract around the hill'. Explaining a term requires more than repeating it in context.

ResultsPlus

Examiner Tip

A useful group revision technique for definitions and descriptions is where one person has to describe or explain a nominated term without using specified words and others have to say what is being described.

Question 13a

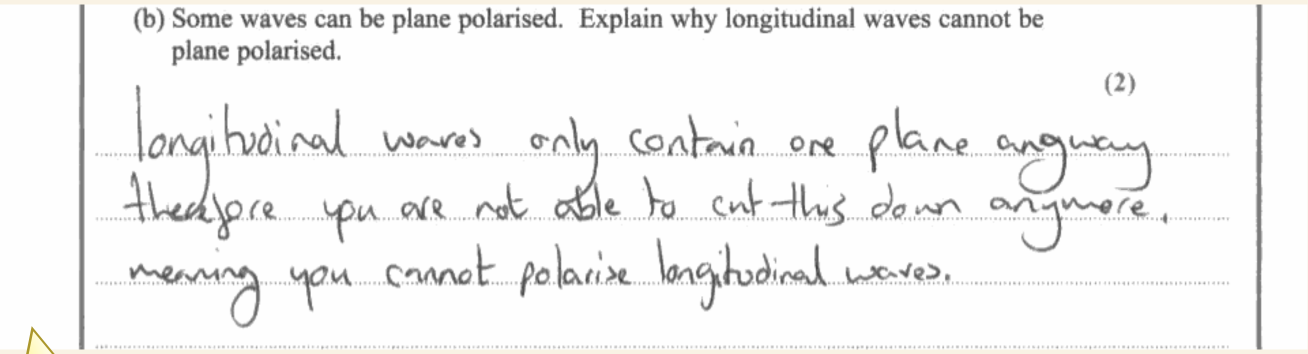
A large majority correctly identified ultrasound. It is possible that some ticked radio because the linked it with the sound given out by radios.

Question 13b

A lack of clarity in the response of many candidates prevented them from gaining credit, even if they seemed to have a fair idea of the reason. Just under half gained a mark for little more than a description of a longitudinal wave after having it suggested by part (a), but very few got a second mark. Candidates rarely described what plane polarisation is in their answers. This is a standard description they should be able to give.

Descriptions involving longitudinal and transverse waves should include reference to ‘oscillation’ or ‘vibration’, but answers often only mentioned ‘movement’. This is ambiguous as it can be applied to the oscillation or the propagation, so answers relying on ‘movement’ gained no credit. For example, ‘longitudinal waves move parallel to the direction of movement’.

There were some valiant efforts at diagrams, but they are very difficult for polarisation and rarely gained credit.



(b) Some waves can be plane polarised. Explain why longitudinal waves cannot be plane polarised.

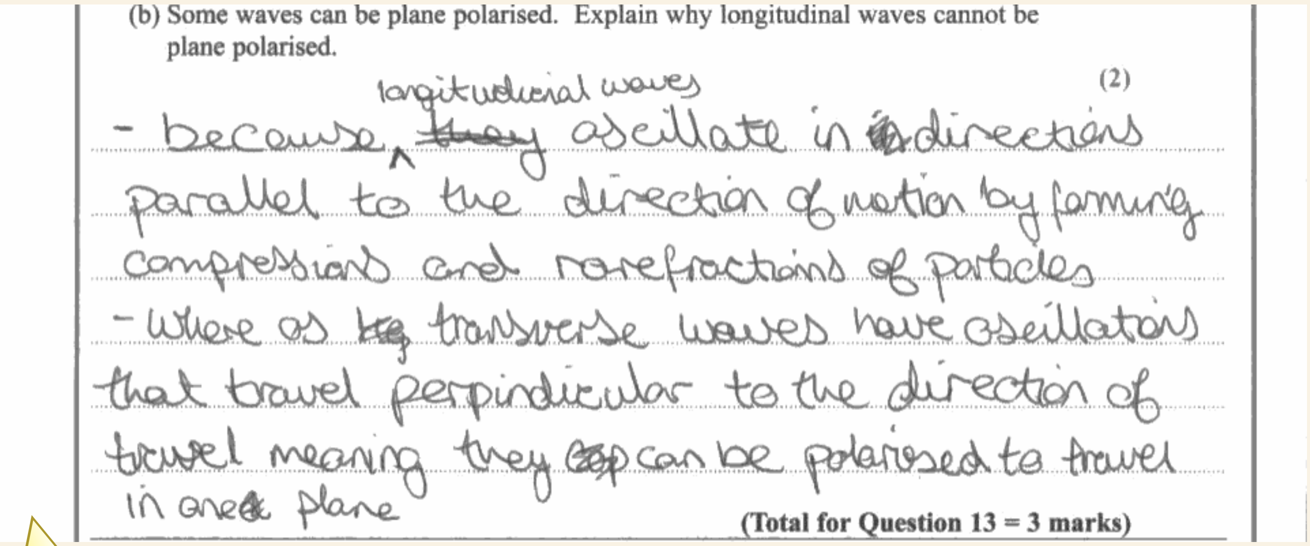
(2)

longitudinal waves only contain one plane anyway therefore you are not able to cut this down anymore, meaning you cannot polarise longitudinal waves.

ResultsPlus

Examiner Comments

While this response appears to contain a sensible reference to planes, it does not mention oscillations or vibrations and therefore gains no credit. It would also need to describe what happens when a wave is polarised.



(b) Some waves can be plane polarised. Explain why longitudinal waves cannot be plane polarised.

(2)

- because, longitudinal waves ~~they~~ oscillate in ~~a~~ directions parallel to the direction of motion by forming compressions and rarefractions of particles
- Where as ~~the~~ transverse waves have oscillations that travel perpindicular to the direction of travel meaning they ~~cap~~ can be polarised to travel in one plane

(Total for Question 13 = 3 marks)

ResultsPlus

Examiner Comments

In the first part of the answer the candidate refers to oscillation parallel to the direction of motion for longitudinal waves. Since oscillation is itself motion, this does not make it clear that it is parallel to the direction of propagation.

In the description of transverse waves, not actually required for this question, the oscillations 'travel perpendicular to the direction of travel', showing similar lack of clarity.

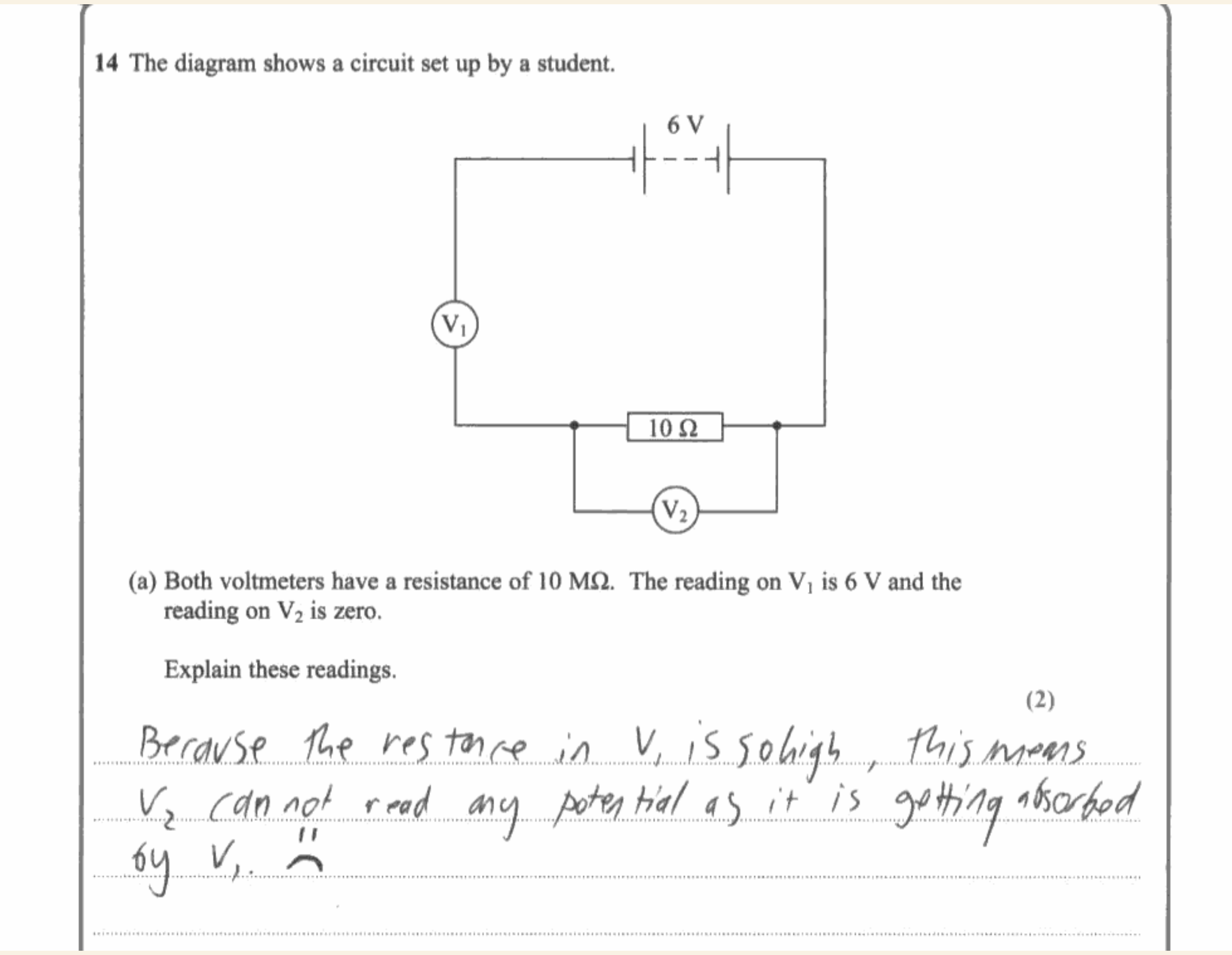
ResultsPlus

Examiner Tip

In descriptions of longitudinal and transverse waves it is best to avoid terms like 'movement', 'motion' and 'move', specifying oscillation and propagation to avoid ambiguity.

Question 14a

About a quarter of answers gained at least one mark, with half of those getting the second mark as well. Those who approached this by carrying out circuit calculations often found it quite straightforward. For the remainder, a number of incomplete approaches and misconceptions were seen, with little understanding of the use of voltmeters with very high resistance. Some candidates simply said that if one reading is 6 V the other must be 0 V to give a total of 6 V, but this information was all in the question. Candidates frequently considered the parallel section of the circuit in isolation and suggested that the voltmeter had no current because all the current flowed through the 10 W resistor instead, and did not realise that there was essentially no current in the whole circuit. There were a number of references to voltage flowing and also to current flowing as far as V_1 and then stopping.



14 The diagram shows a circuit set up by a student.

(a) Both voltmeters have a resistance of 10 MΩ. The reading on V_1 is 6 V and the reading on V_2 is zero.

Explain these readings.

(2)

Because the restance in V_1 is so high, this means V_2 can not read any potential as it is getting absorbed by V_1.

ResultsPlus

Examiner Comments

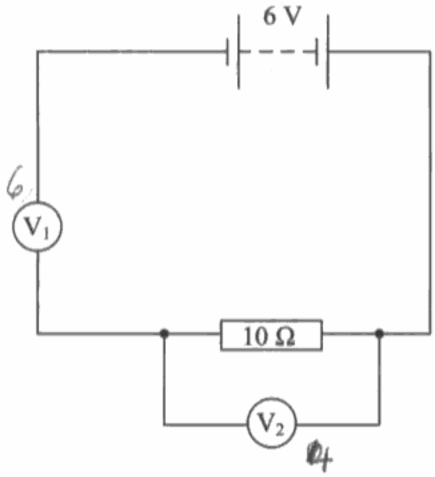
This candidate has mentioned that V_1 is high, but has not made it clear that it is very high in comparison to the parallel combination which contains an equally high resistance. The statement that potential is 'getting absorbed' is not an adequate description.

ResultsPlus

Examiner Tip

When comparing things it is generally necessary to make a contextual reference to each of them in the response.

14 The diagram shows a circuit set up by a student.



(a) Both voltmeters have a resistance of 10 MΩ. The reading on V_1 is 6 V and the reading on V_2 is zero.

Explain these readings.

(2)

~~[illegible]~~ Going into the junction, the current is split. As the 10Ω resistor ~~tha~~ takes all the current ~~[illegible]~~ the reading on $V_2 = 0$ because $V = IR$

ResultsPlus

Examiner Comments

This response fails to recognise that the potential difference across parallel components is equal and is attempting to suggest the reading on V_2 is zero because its current is zero due to the current going through the resistor instead. It is comparing the resistor and its voltmeter and ignoring V_1.

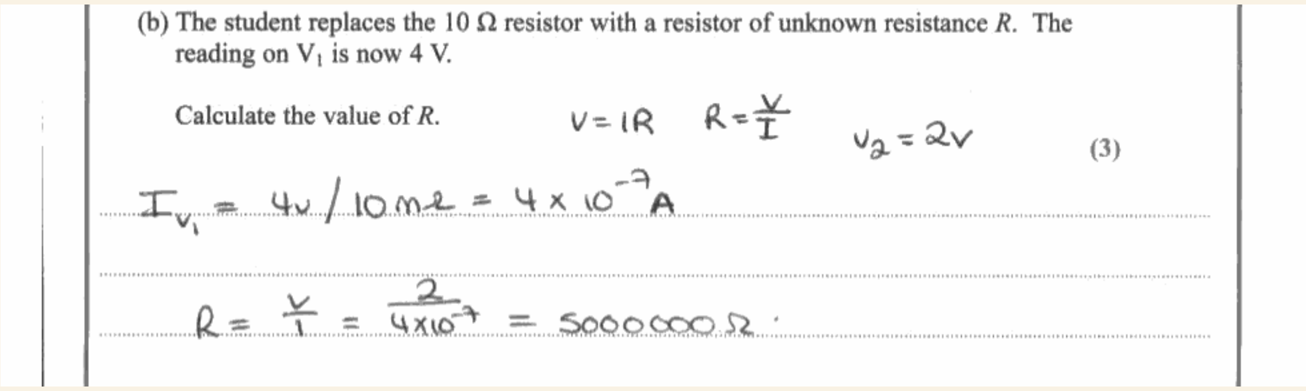
Candidates are expected to know that a voltmeter has a very high resistance specifically to ensure it draws very little current.

Question 14b

This was slightly less well answered than part (a), with about a quarter of answers gaining at least one mark, and a quarter of those also getting the second and third marks.

The most common way to get a single mark was finding the resistance of the parallel section of the circuit, although most candidates thought this was the final answer required, ignoring V_2, or perhaps thinking it had been removed.

Some candidates got the final answer after assuming the current in the circuit divided equally between the parallel branches, although this is not always the case.



(b) The student replaces the 10 Ω resistor with a resistor of unknown resistance *R*. The reading on V_1 is now 4 V.

Calculate the value of *R*. $V = IR$ $R = \frac{V}{I}$ $V_2 = 2v$

(3)

$I_{V_1} = 4v / 10M\Omega = 4 \times 10^{-7} A$

$R = \frac{V}{I} = \frac{2}{4 \times 10^{-7}} = 5000000 \Omega$

ResultsPlus

Examiner Comments

This is a typical response in which the candidate has just found the resistance of the parallel section of the circuit, as if the resistor and V_2 had both been removed and replaced by the new resistance *R*.

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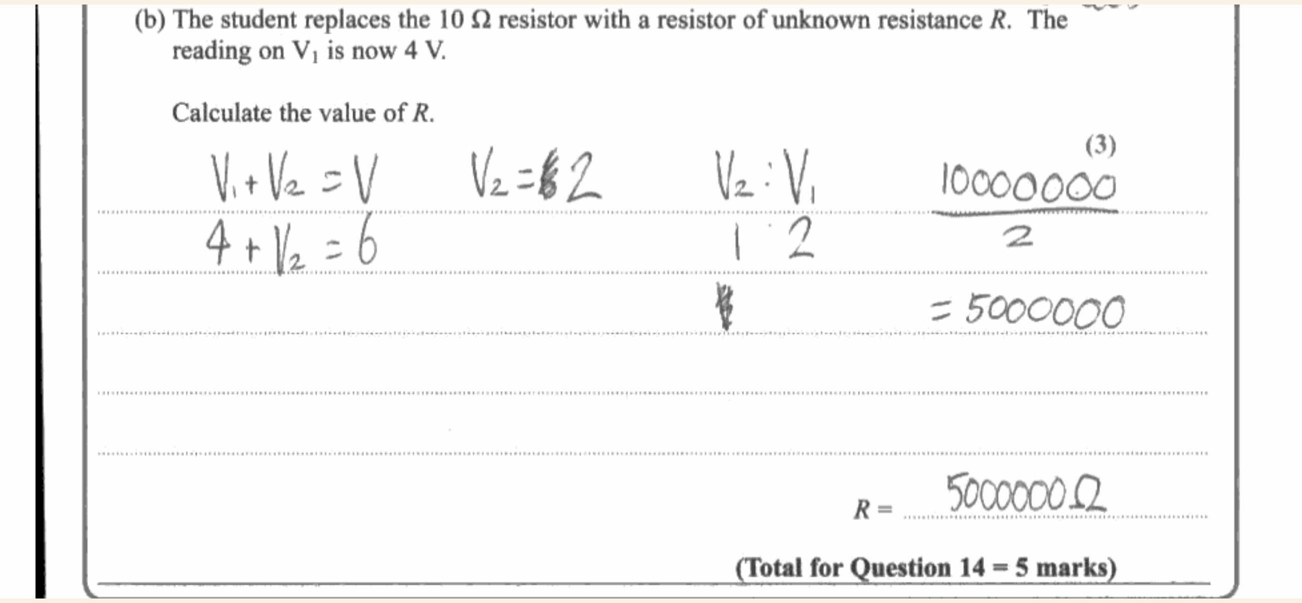
Examiner Tip

Be careful to correctly identify the context. In this case, altering the original circuit diagram or drawing a new one would have clarified the situation.



(b) The student replaces the 10 Ω resistor with a resistor of unknown resistance R. The reading on V_1 is now 4 V.

Calculate the value of R.

(3)

$V_1 + V_2 = V$

$4 + V_2 = 6$

$V_2 = \cancel{8}2$

$V_2 : V_1$

$1 : 2$

$\frac{10000000}{2}$

$= 5000000$

$R =$ 5000000 Ω

(Total for Question 14 = 5 marks)

ResultsPlus

Examiner Comments

This candidate has also only calculated the new resistance of the parallel section, but by the alternative method of applying the ratio of the potential differences.

Question 15

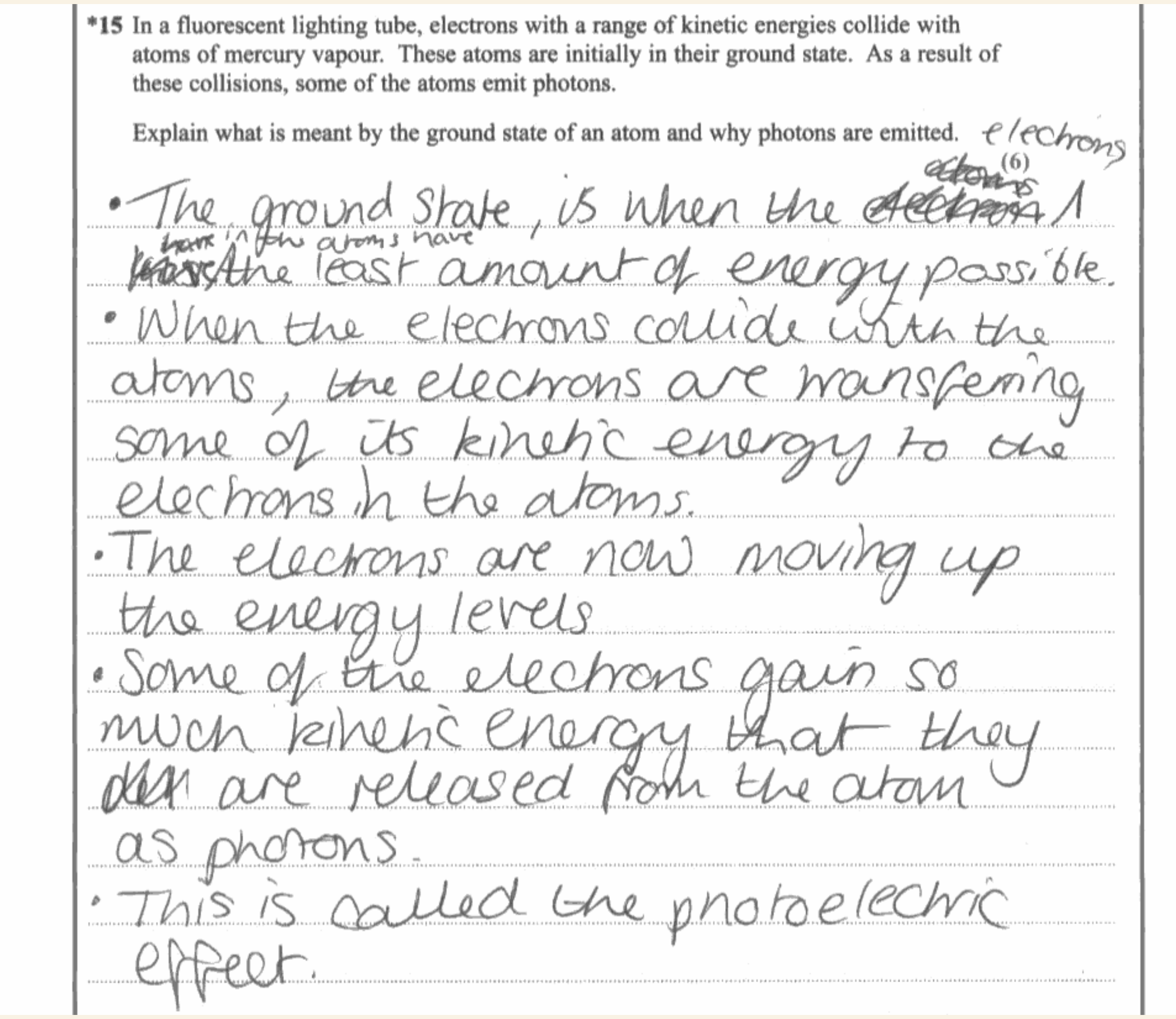
The required answer here was a slightly simpler version of a typical atomic spectra explanation, an example of a typical 'set piece' response. While slightly over half the entry got 3 marks, a good minority were awarded 5 or 6 out of 6 for clear and logically organised answers using correct technical wording.

There was a lot of confusion with the photoelectric effect, even with some answers that got 4 marks for correct points. Some seemed to confuse photons with photoelectrons, with references to photons changing energy levels and to electrons being emitted as photons.

A number of candidates failed to mention energy levels explicitly, and others were rather vague in explaining the ground state, sometimes saying it was where the atom had zero energy.

Although collisions made up most of the stem of the question, they weren't always mentioned in answers in the context of energy transfer to the atoms.

Answers generally referred to electrons moving to higher energy levels and then moving down again, and also frequently to the energy being emitted in the form of photons rather than just repeating from the question that photons were emitted.



*15 In a fluorescent lighting tube, electrons with a range of kinetic energies collide with atoms of mercury vapour. These atoms are initially in their ground state. As a result of these collisions, some of the atoms emit photons.

Explain what is meant by the ground state of an atom and why photons are emitted. (6)

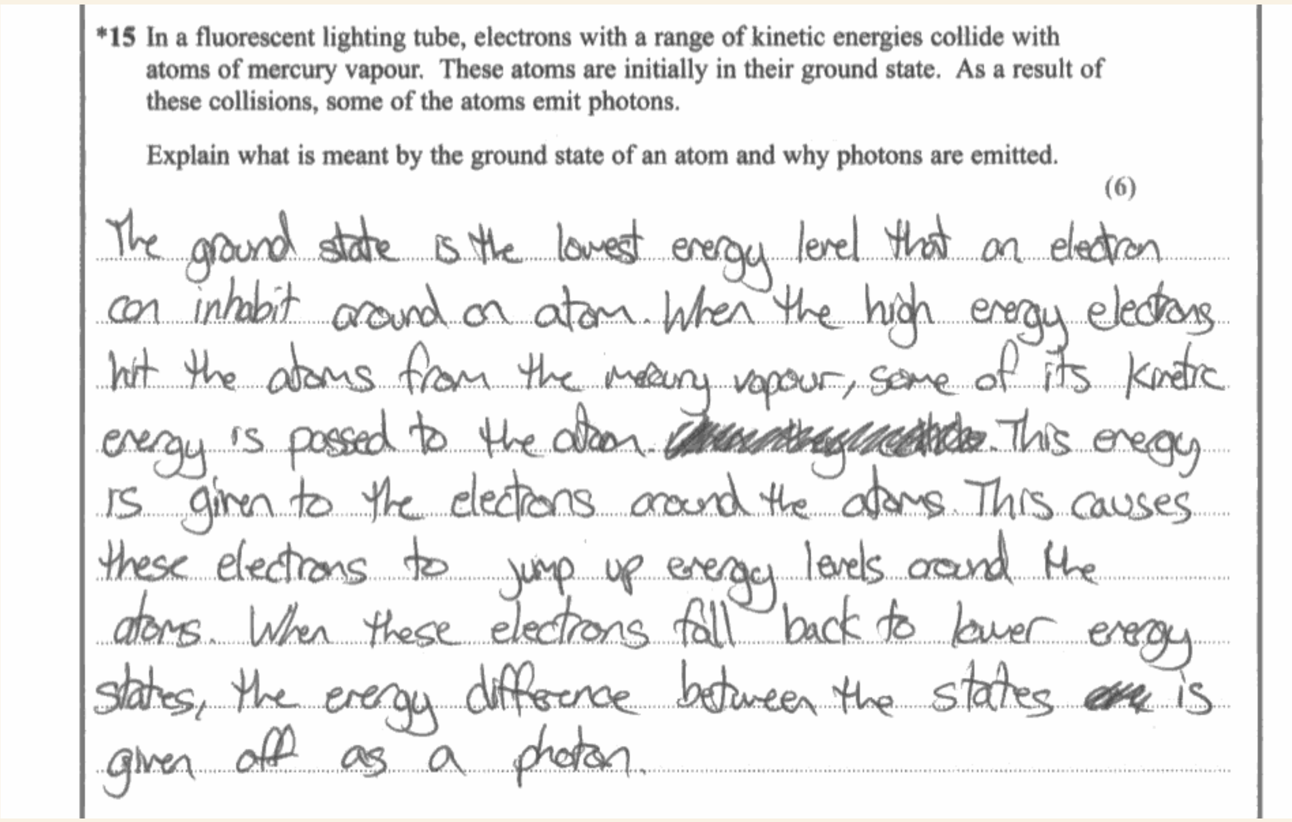
- The ground state, is when the ~~electron~~ ~~atoms~~ electrons in the atoms have ~~has~~ the least amount of energy possible.
- When the electrons collide with the atoms, the electrons are transferring some of its kinetic energy to the electrons in the atoms.
- The electrons are now moving up the energy levels
- Some of the electrons gain so much kinetic energy that they ~~did~~ are released from the atom as photons.
- This is called the photoelectric effect.

ResultsPlus
Examiner Comments

This response starts off well and gets four marks out of six, but it becomes clear by the end that the candidate is getting the photoelectric effect and atomic spectra confused, even suggesting that electrons are emitted 'as photons'.

ResultsPlus
Examiner Tip

Learn standard descriptions thoroughly, and be sure to know the difference between photons and photoelectrons.



*15 In a fluorescent lighting tube, electrons with a range of kinetic energies collide with atoms of mercury vapour. These atoms are initially in their ground state. As a result of these collisions, some of the atoms emit photons.

Explain what is meant by the ground state of an atom and why photons are emitted.

(6)

The ground state is the lowest energy level that an electron can inhabit around an atom. When the high energy electrons hit the atoms from the mercury vapour, some of its kinetic energy is passed to the atom. ~~[illegible]~~. This energy is given to the electrons around the atoms. This causes these electrons to jump up energy levels around the atoms. When these electrons fall back to lower energy states, the energy difference between the states ~~are~~ is given off as a photon.

ResultsPlus

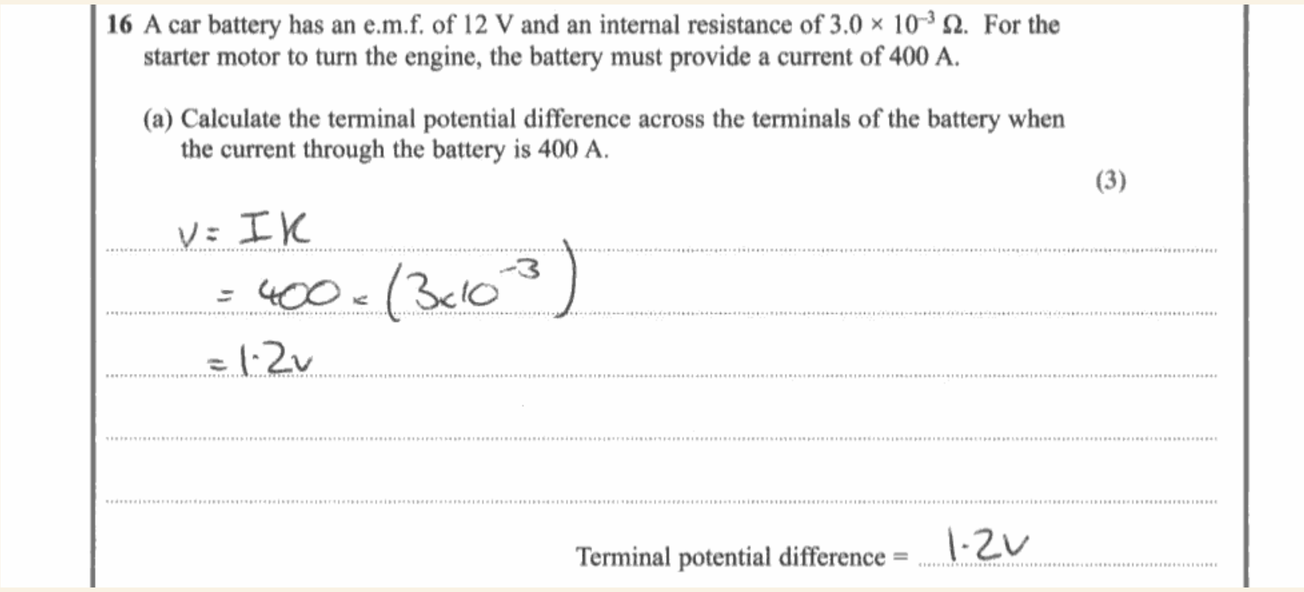
Examiner Comments

This is a typical full mark response which sets out the relevant points concisely and in a logical order, using the correct terms at each stage.

Question 16a

The great majority scored at least 1 for using $V = IR$, with half the entry getting full marks for finding the terminal potential difference correctly.

Some of those not getting the final answer wrote $V = E - Ir$, but got V and E confused to get an answer of 13.2 V. Most of the others thought 1.2 V was the required answer. Diagrams were rarely seen.



16 A car battery has an e.m.f. of 12 V and an internal resistance of 3.0×10^{-3} Ω. For the starter motor to turn the engine, the battery must provide a current of 400 A.

(a) Calculate the terminal potential difference across the terminals of the battery when the current through the battery is 400 A.

(3)

$V = IR$

$= 400 \times (3\times10^{-3})$

$= 1.2V$

Terminal potential difference = 1.2V

ResultsPlus

Examiner Comments

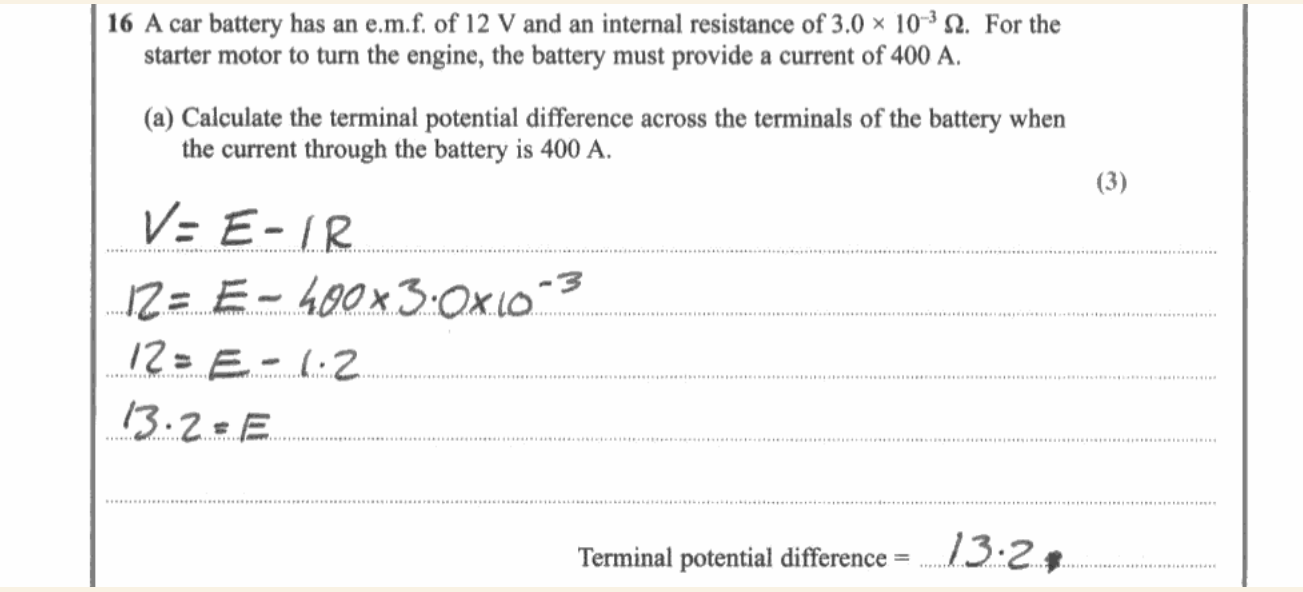
This response shows the use of $V = IR$ to calculate the 'lost volts', but treats this as the final answer.

This value should have been subtracted from the e.m.f. to find the terminal p.d.

ResultsPlus

Examiner Tip

Using r as the symbol for internal resistance rather than R might well have reminded this candidate of the correct equation to apply.



16 A car battery has an e.m.f. of 12 V and an internal resistance of $3.0 \times 10^{-3}\ \Omega$. For the starter motor to turn the engine, the battery must provide a current of 400 A.

(a) Calculate the terminal potential difference across the terminals of the battery when the current through the battery is 400 A.

(3)

$V = E - IR$

$12 = E - 400 \times 3.0 \times 10^{-3}$

$12 = E - 1.2$

$13.2 = E$

Terminal potential difference = 13.2

ResultsPlus

Examiner Comments

The correct equation has been given, but has then been misapplied by using the value of e.m.f. as the terminal p.d. The candidate does not appear to know that *E* is e.m.f. and *V* is terminal p.d.

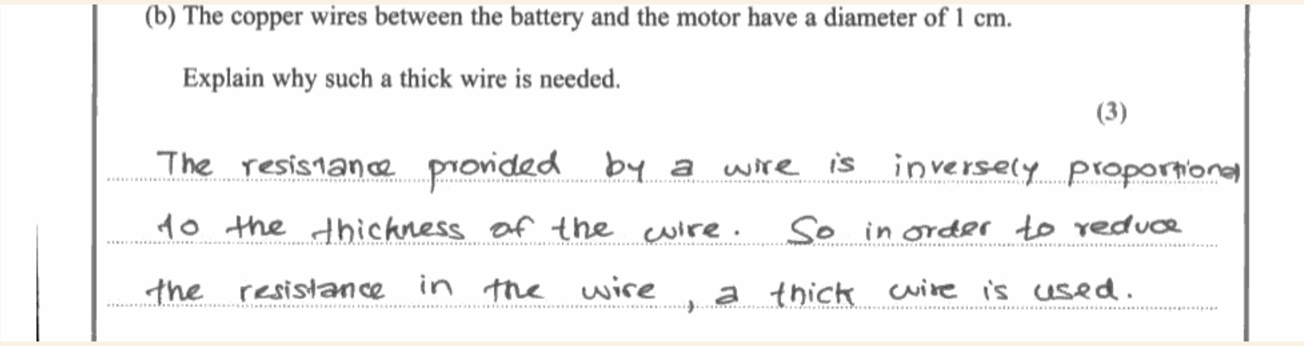
ResultsPlus

Examiner Tip

Learn all the symbols used in equations and carefully identify each before substitution for calculations.

Question 16b

A majority got 2 marks, but few got 3. 2 mark answers could have missed any of the three required points, either failing to indicate the relevance of the 400 A current, not linking thickness to a large cross-sectional area or not mentioning a low resistance. These candidates may have benefited from considering whether they had made three distinct points which could be awarded marks. Candidates attempting to use $I = nAqv$ alone did not score full marks. 'Area' was accepted for 'cross-sectional area', but a few candidates explicitly stated 'surface area', removing the ambiguity and the chance for a mark.



(b) The copper wires between the battery and the motor have a diameter of 1 cm.

Explain why such a thick wire is needed.

(3)

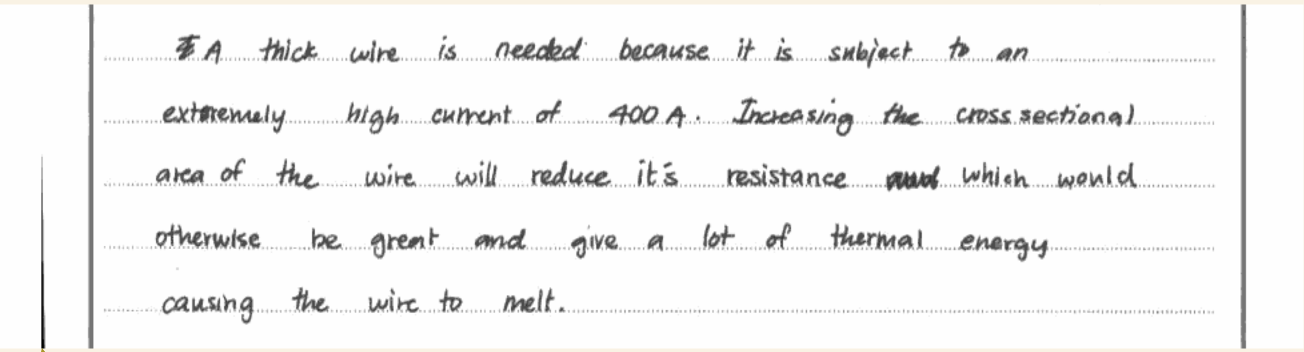
The resistance provided by a wire is inversely proportional to the thickness of the wire. So in order to reduce the resistance in the wire, a thick wire is used.

ResultsPlus

Examiner Comments

The candidate has identified the need for a low resistance, but has only repeated the question in referring to a thick wire and failing to link it to large cross-sectional area.

In addition, the full explanation needs to say why low resistance is needed by reference to the large current or its effects.



A thick wire is needed because it is subject to an extremely high current of 400 A. Increasing the cross sectional area of the wire will reduce it's resistance ~~and~~ which would otherwise be great and give a lot of thermal energy causing the wire to melt.

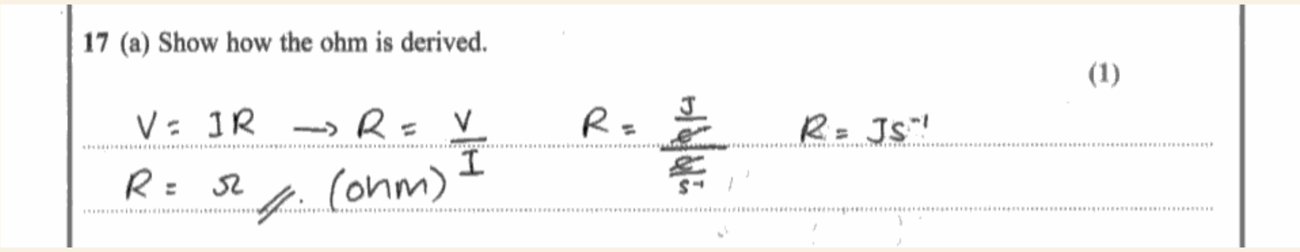
ResultsPlus

Examiner Comments

This is an example of a well structured, full mark response. It states the relevance of the large current and establishes how a low resistance can be achieved.

Question 17a

A large majority correctly gave the relevant units or quoted $R = V/I$ for the mark. Those that didn't frequently attempted to use resistivity but were not credited because this already included the ohm.



17 (a) Show how the ohm is derived.

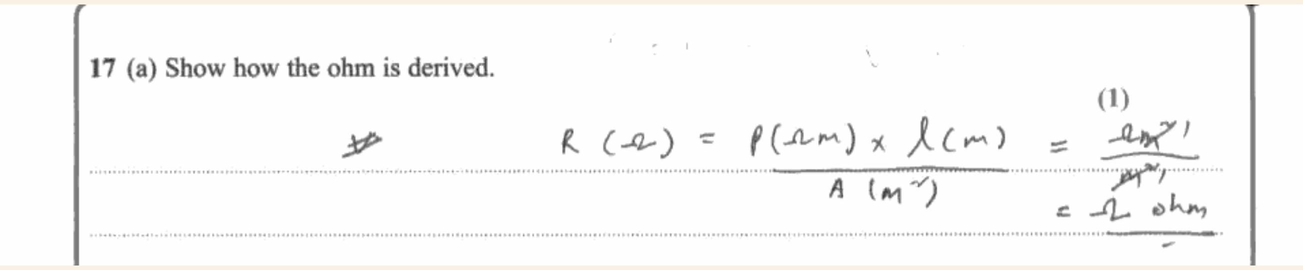
(1)

$V = IR \rightarrow R = \frac{V}{I}$ $R = \frac{J/\cancel{C}}{\cancel{C}/s^{-1}}$ $R = Js^{-1}$

$R = \Omega$ // (ohm)

ResultsPlus
Examiner Comments

This response gets the mark by identifying the starting point for the derivation, but it is notable that a number of candidates seemed content, after incorrectly dividing fractions, to say that an ohm is the same as a watt.



17 (a) Show how the ohm is derived.

(1)

$R\ (\Omega) = \frac{\rho(\Omega m) \times l(m)}{A\ (m^2)} = \frac{\Omega \cancel{m^2}}{\cancel{m^2}}$

$= \Omega$ ohm

ResultsPlus
Examiner Comments

This response attempts to use a unit already containing ohms to derive ohms.

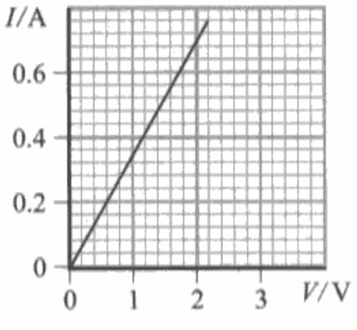
ResultsPlus
Examiner Tip

A unit cannot be used to derive itself.

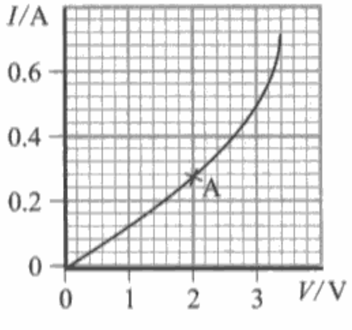
Question 17bi

While the majority gained full marks for an answer in the required range, about a tenth lost a mark by misreading the current value. Current was sometimes quoted as 2.2 A or 2.4 A, indicating that they looked at the last marked *I* value below the point on the *y* axis and counted up to point A without referring to the rest of the scale to establish the value of each division.

A minority of candidates drew a tangent at A and calculated its gradient, using the inverse as their resistance value. This misconception, that the gradient of a potential difference-current graph gives resistance, was also seen in part (b) (ii). While not exactly widespread, it is not uncommon either, even among recent graduates. AS level students will often bring this idea with them from GCSE. It is stated that the gradient equals resistance in some GCSE text books with reference to the straight line *V-I* graph for a metal, and some books state that the gradient for this graph is just *numerically* equal to resistance, but by then it has lodged with some students and subsequent qualification for other curves fails to be internalised. Students are used to other cases where a straight line graph is seen before applying the gradient to curves, e.g. for displacement-time graphs, so they need to know that this relationship is not a rate of change. Perhaps learning resistance thoroughly before doing experiments leading to *V-I* graphs would help, along with pointing out that Ohm's law really just says that resistance is constant in the defined situation and linking it to the constant ratio along the line rather than a gradient. For curves this might be demonstrated with lines from the origin to the point in question which are clearly not tangents.



Metal conductor



Thermistor

(i) Calculate the resistance of the thermistor at point A.

(2)

R = V / I

2 / 0·22

= 9·09 Ω

Resistance = 9·09 Ω

ResultsPlus

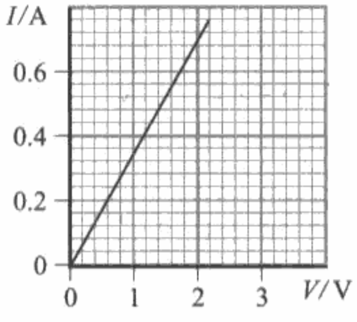
Examiner Comments

This candidate has misread the current scale, apparently taking each small square after 0.2 A as 0.01 A, and just gets the first mark for use of the correct equation.

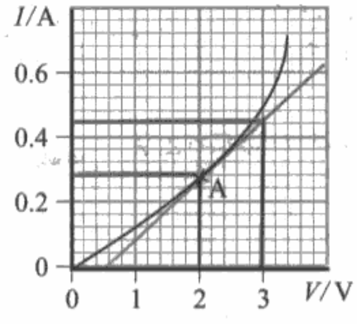
ResultsPlus

Examiner Tip

Read graph scales carefully, looking at the marked values above and below the relevant point to establish the value of each square.



Metal conductor



Thermistor

(i) Calculate the resistance of the thermistor at point A. (2)

$R = \frac{V}{I}$ $\frac{1}{\text{gradient}} = \frac{1}{R} = \frac{3-2}{0.44 - 0.28}$

$\frac{1}{R} = 0.16$ ∴

$R = 6.25\ \Omega$

Resistance = $6.25\ \Omega$

ResultsPlus

Examiner Comments

This is a clear example, fortunately rare, of the gradient being calculated.

ResultsPlus

Examiner Tip

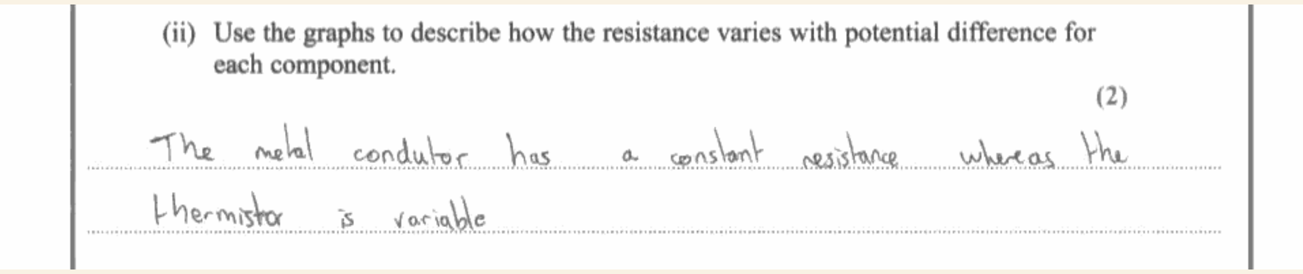
Resistance is defined using $R = V/I$. It is not the gradient of a graph of p.d. against current, and must be calculated using the single values of p.d. and current at the relevant point.

Question 17bii-iii

17 (b)(ii) Most candidates knew that resistance is constant for the metal and changes for the thermistor, although they did not all state that the change was a decrease.

Some misinterpreted the graphs as if they were resistance against potential difference, saying, for example, that resistance is proportional to p.d. for a metal. There were more references to gradient in this part than attempts to use a tangent in part (b) (i), but the mark was given for the correct description of variation and not the justification from the graph so they were not penalised.

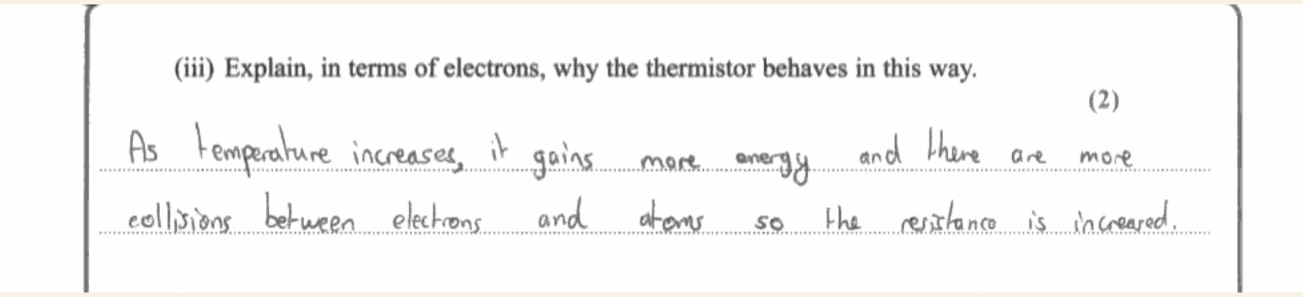
17 (b) (iii) Performance fell off for this part with 2 mark answers being rare, and 1 mark answers were more likely to refer to more charge carriers than to the current causing a temperature increase. Many students described a metal and gave the 'set piece' answer for the increase of resistance with temperature, even if they had identified constant resistance for a metal and decreasing resistance for a thermistor from the graphs. Some suggested that faster electrons meant a larger current. Many candidates were not aware of the difference between semiconductors and metals.



(ii) Use the graphs to describe how the resistance varies with potential difference for each component.

(2)

The metal condutor has a constant resistance whereas the thermistor is variable



(iii) Explain, in terms of electrons, why the thermistor behaves in this way.

(2)

As temperature increases, it gains more energy and there are more collisions between electrons and atoms so the resistance is increased.

ResultsPlus

Examiner Comments

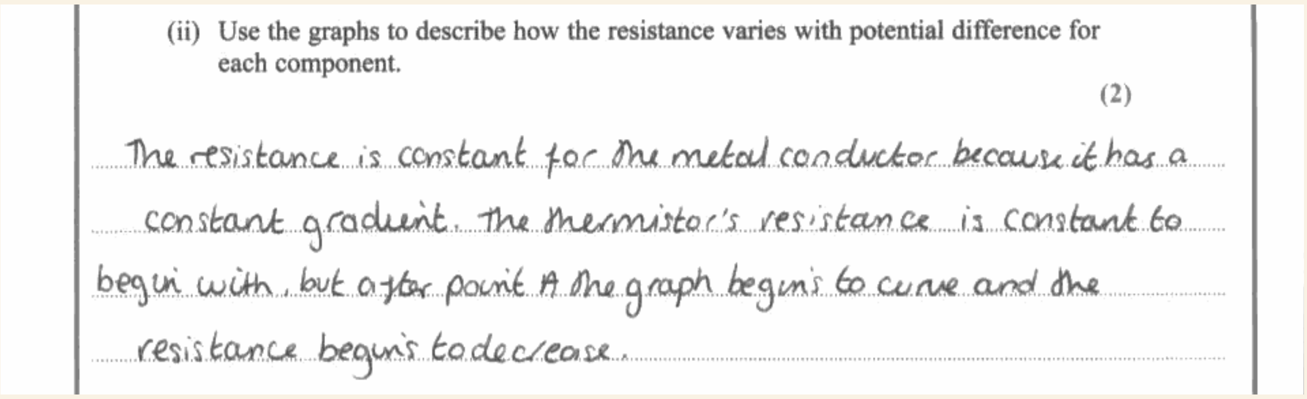
In b) ii) the constant resistance for the metal is identified. The resistance of the thermistor is described as variable, but the candidate needs to say how it varies, i.e. whether it increases or decreases.

In b) iii) the candidate is describing the effect of temperature on a metallic conductor rather than a thermistor.

ResultsPlus

Examiner Tip

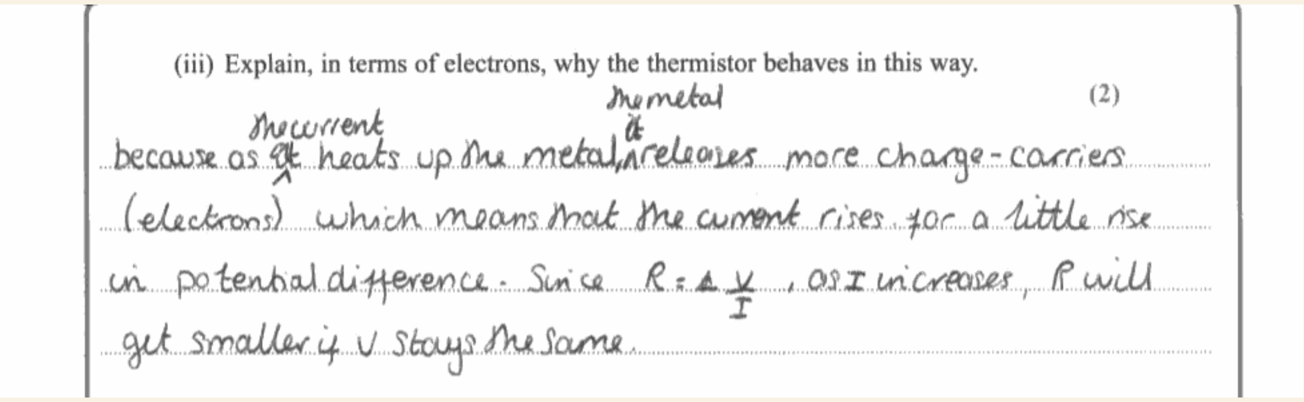
You are advised to learn standard descriptions, such as the effect of temperature on resistance, but make sure you are applying these to the situation described in the question and not just thinking of a previous question you have used for practice.



(ii) Use the graphs to describe how the resistance varies with potential difference for each component.

(2)

The resistance is constant for the metal conductor because it has a constant gradient. The thermistor's resistance is constant to begin with, but after point A the graph begins to curve and the resistance begins to decrease.



(iii) Explain, in terms of electrons, why the thermistor behaves in this way.

(2)

because as ~~it~~ the current heats up the metal, ~~it~~ the metal releases more charge-carriers (electrons) which means that the current rises for a little rise in potential difference. Since $R = \Delta \frac{V}{I}$, as I increases, R will get smaller if V stays the same.

ResultsPlus

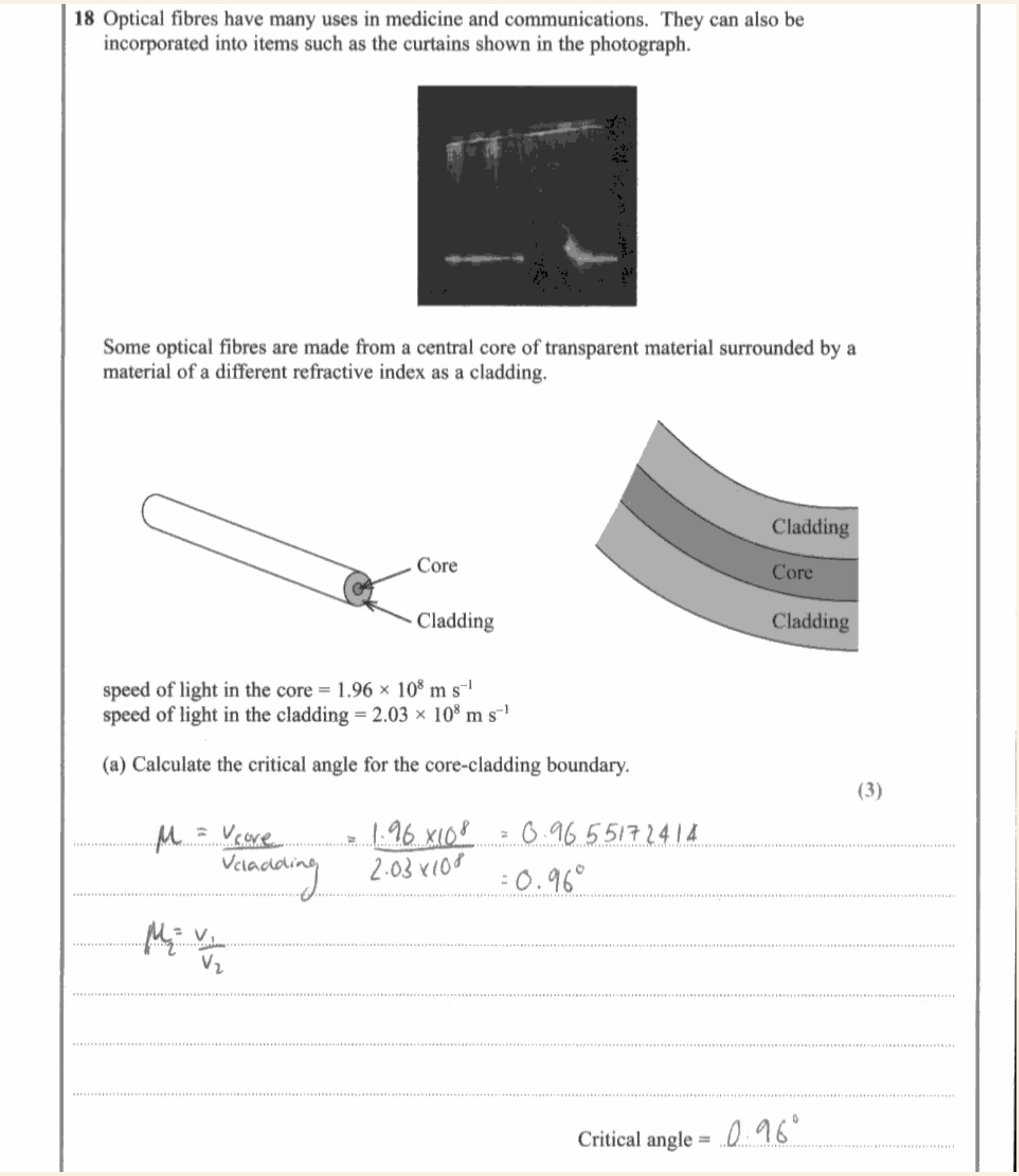
Examiner Comments

Although this answer to b) ii) is in terms of gradient rather than the ratio of *V* to *I*, the marks were awarded for the correct description of the resistance in each case.

b) iii) correctly identifies the current causing a temperature rise and the release of charge carriers, even though some of the other details are not quite correct.

Question 18

A good majority scored at least 4 marks for the whole question, 4 being the median mark, with marking patterns of 310 and 112 both seen fairly frequently. For some reason, those calculating the critical angle were less likely to describe the light in the curtains correctly and vice versa. In part (a) it was not always obvious whether candidates were entirely clear about how they reached their answer since the value of a sine must be less than 1 and there was only one way to get that. The ${}_1m_2$ etc notation was confusing for some and m sin i = constant might be a helpful approach. Some candidates didn't realise that rounding sine values would make such a significant difference to their answers and should be aware of this in future as, if this had been presented in 'show that' form they might have thought they had the wrong answer. Part (b) was rarely incorrect, with a few suggesting refraction would take place and the bet-hedging term 'reflaction' being seen rarely. Students often seemed to have the idea in part (c) without being able to express it clearly. They sometimes only got the last mark because they were not explicit about the repeated reflection down the fibre.



18 Optical fibres have many uses in medicine and communications. They can also be incorporated into items such as the curtains shown in the photograph.

Some optical fibres are made from a central core of transparent material surrounded by a material of a different refractive index as a cladding.

speed of light in the core = 1.96×10^8 m s^{-1}
speed of light in the cladding = 2.03×10^8 m s^{-1}

(a) Calculate the critical angle for the core-cladding boundary.

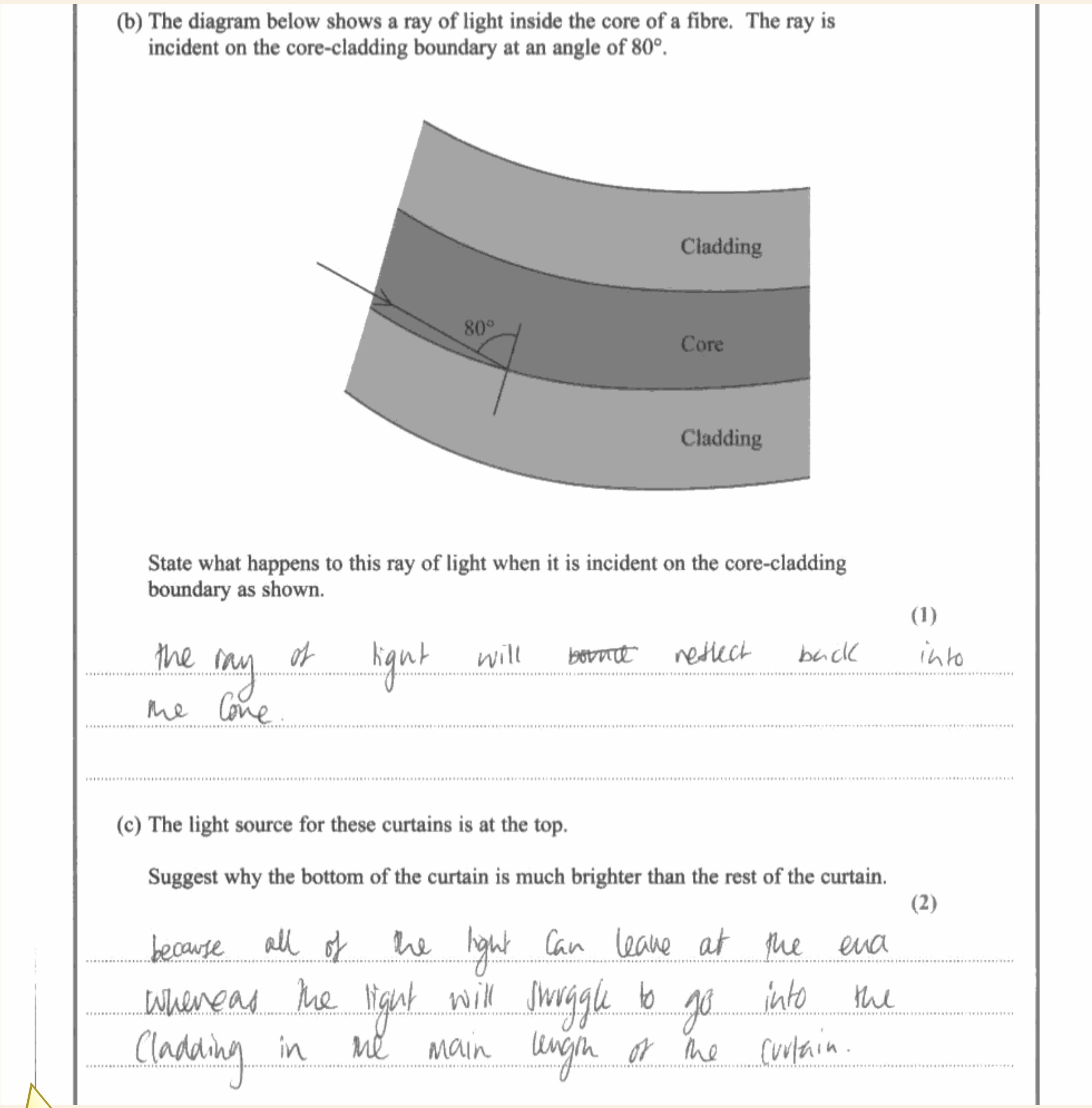
(3)

$\mu = \frac{v_{core}}{v_{cladding}} = \frac{1.96 \times 10^8}{2.03 \times 10^8} = 0.9655172414$

$= 0.96°$

$\mu_2 = \frac{v_1}{v_2}$

Critical angle = 0.96°



(b) The diagram below shows a ray of light inside the core of a fibre. The ray is incident on the core-cladding boundary at an angle of 80°.

State what happens to this ray of light when it is incident on the core-cladding boundary as shown.

(1)

the ray of light will ~~bounce~~ reflect back into the core.

(c) The light source for these curtains is at the top.

Suggest why the bottom of the curtain is much brighter than the rest of the curtain.

(2)

because all of the light can leave at the end whereas the light will struggle to go into the cladding in the main length of the curtain.

ResultsPlus

Examiner Comments

In a), given just two numbers, dividing one by the other is one of a limited number of options, and the formula used was then selected from the data sheet. The candidate has not remembered that *m* stands for refractive index and has simply taken it to be the required angle.

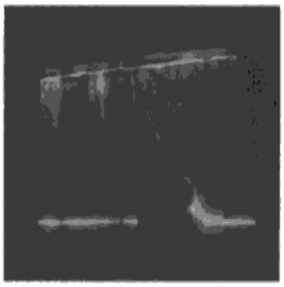
This answer refers to reflection correctly in b), but does not apply it fully in c), just saying that the light would 'struggle to get into the cladding'. Having used the correct terminology earlier, it should have been clear that verbs such as 'struggle' are not appropriate to inanimate contexts and the idea of reflection should have been applied again. There should generally be an expectation that ideas from earlier parts of questions will be developed in later parts.

ResultsPlus

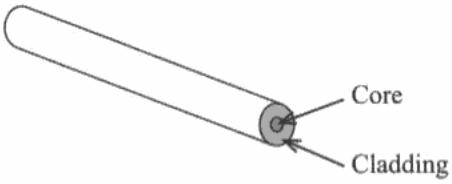
Examiner Tip

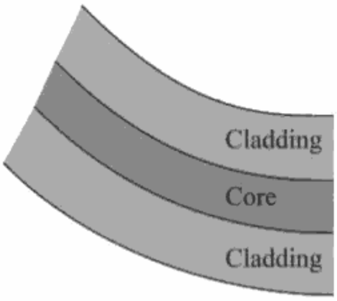
Apply scientific terminology at all times.

18 Optical fibres have many uses in medicine and communications. They can also be incorporated into items such as the curtains shown in the photograph.



Some optical fibres are made from a central core of transparent material surrounded by a material of a different refractive index as a cladding.





speed of light in the core = 1.96×10^8 m s^{-1}
speed of light in the cladding = 2.03×10^8 m s^{-1}

(a) Calculate the critical angle for the core-cladding boundary.

(3)

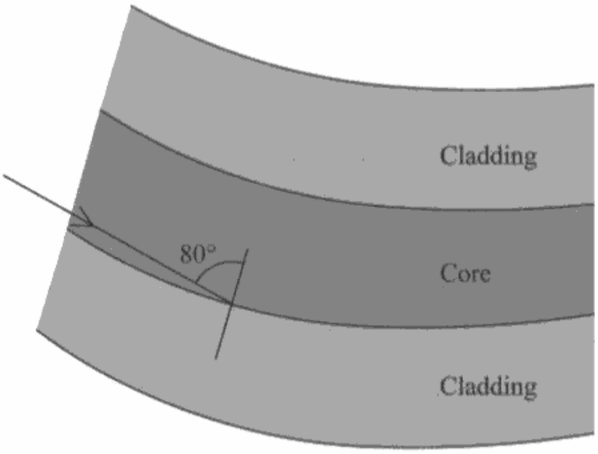
$${}_1\mu_2 = \frac{1.96\times10^8}{2.03\times10^8} = 0.975$$

$$\frac{2.03\times10^8}{1.96\times10^8} = 1.036 \qquad \sin c = \frac{0.975}{1.036}$$

$$\sin^{-1}\left(\frac{0.975}{1.036}\right) = 70.2^\circ$$

Critical angle = 70.2°

(b) The diagram below shows a ray of light inside the core of a fibre. The ray is incident on the core-cladding boundary at an angle of 80°.



State what happens to this ray of light when it is incident on the core-cladding boundary as shown.

(1)

The light would be totally internally reflected.

(c) The light source for these curtains is at the top.

Suggest why the bottom of the curtain is much brighter than the rest of the curtain.

(2)

Because at the bottom of the curtain all the light is allowed to escape from the opticle fibres where as before most of the light was continually reflected and very little light was transmitted.

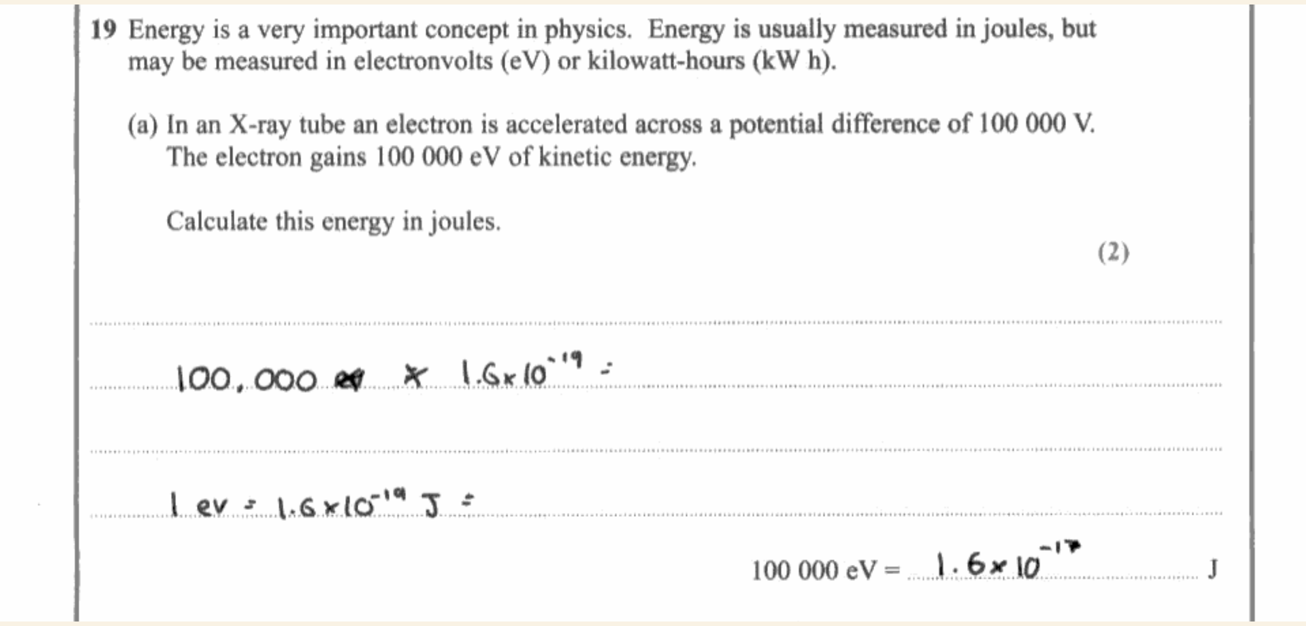
ResultsPlus
Examiner Comments

a) The candidate has adopted the correct approach to the problem, but has gone on to get the media in the wrong order. It may be that using the approach *m* sin *i* = constant is a more useful method for solving refractive index problems as it avoids this problem.

Part b) is correct and it is applied appropriately to answer part c).

Question 19a

The majority got this correct, with a few dividing the numbers or making mistakes with powers of 10.



19 Energy is a very important concept in physics. Energy is usually measured in joules, but may be measured in electronvolts (eV) or kilowatt-hours (kW h).

(a) In an X-ray tube an electron is accelerated across a potential difference of 100 000 V. The electron gains 100 000 eV of kinetic energy.

Calculate this energy in joules.

(2)

$100,000 \times 1.6\times10^{-19} =$

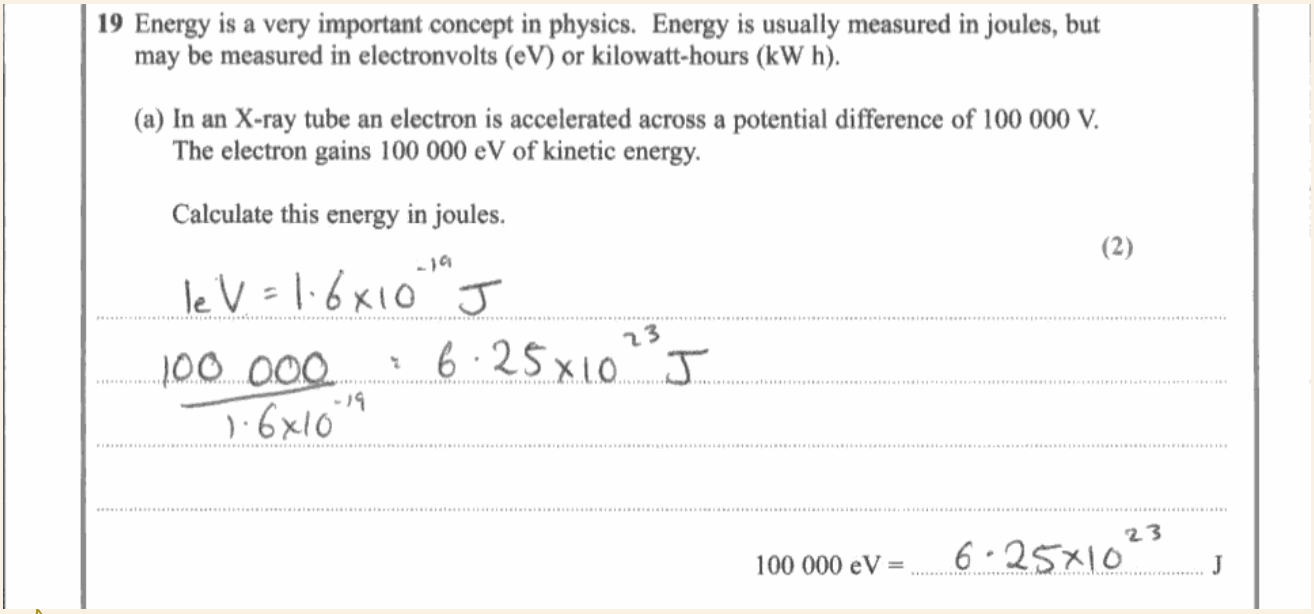
$1\ \mathrm{ev} = 1.6\times10^{-19}\ \mathrm{J} =$

100 000 eV = 1.6×10^{-17} J

ResultsPlus

Examiner Comments

Candidates occasionally make slips like this, multiplying by 100 rather than 100 000.



19 Energy is a very important concept in physics. Energy is usually measured in joules, but may be measured in electronvolts (eV) or kilowatt-hours (kW h).

(a) In an X-ray tube an electron is accelerated across a potential difference of 100 000 V. The electron gains 100 000 eV of kinetic energy.

Calculate this energy in joules.

(2)

$1\mathrm{eV} = 1{\cdot}6\times10^{-19}\ \mathrm{J}$

$\frac{100\ 000}{1{\cdot}6\times10^{-19}} = 6{\cdot}25\times10^{23}\ \mathrm{J}$

100 000 eV = $6{\cdot}25\times10^{23}$ J

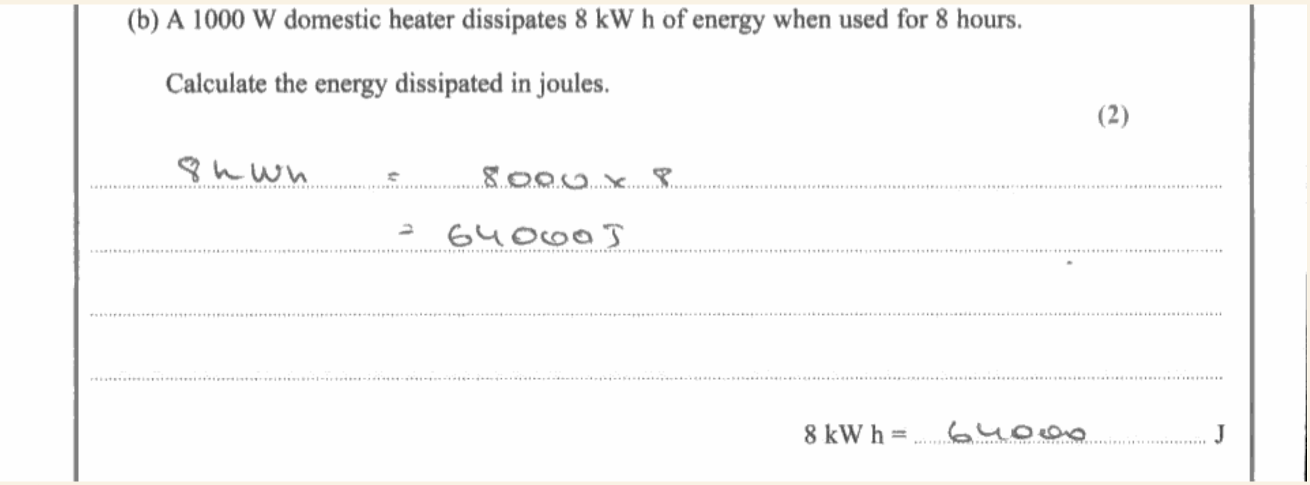
ResultsPlus

Examiner Comments

Some candidates used the value of eV from the data sheet, but divided instead of multiplying.

Question 19b

Only about a third got this fully correct, and under half got credit for power x time. This was often because they misread the question and applied the factor 8 twice, assuming it was 8 kW for 8 hours. They usually converted time to seconds correctly.



(b) A 1000 W domestic heater dissipates 8 kW h of energy when used for 8 hours.

Calculate the energy dissipated in joules.

(2)

8kWh = 8000 × 8

= 64000J

8 kW h = 64000 J

ResultsPlus

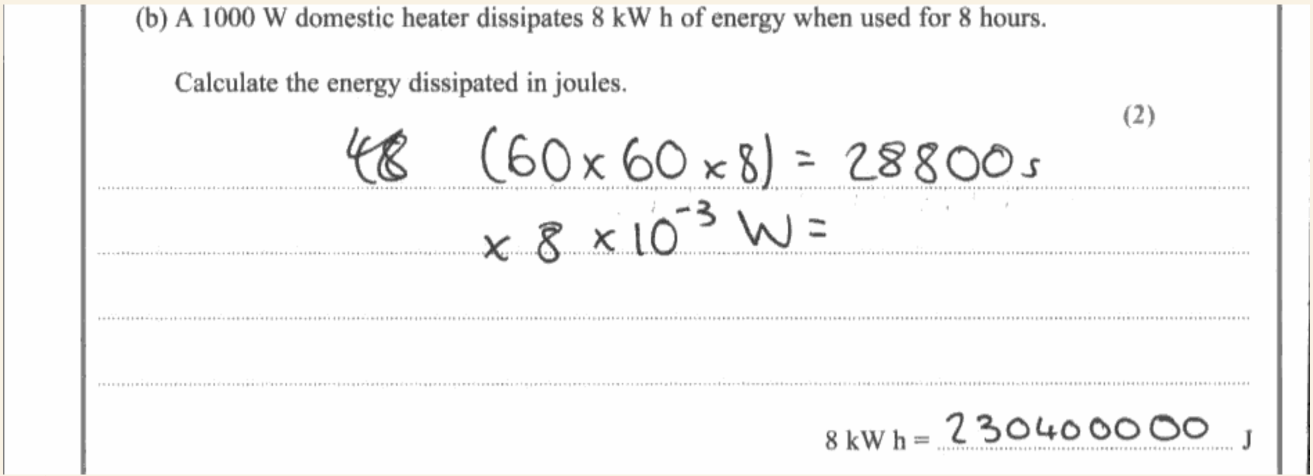
Examiner Comments

This response combines two errors. The power has been taken as 8 kW and the time has been left in hours.

ResultsPlus

Examiner Tip

For answers in SI units, time must be in seconds.



(b) A 1000 W domestic heater dissipates 8 kW h of energy when used for 8 hours.

Calculate the energy dissipated in joules.

(2)

48 $(60 \times 60 \times 8) = 28800\,s$

$\times 8 \times 10^{-3}$ W =

8 kW h = 230400000 J

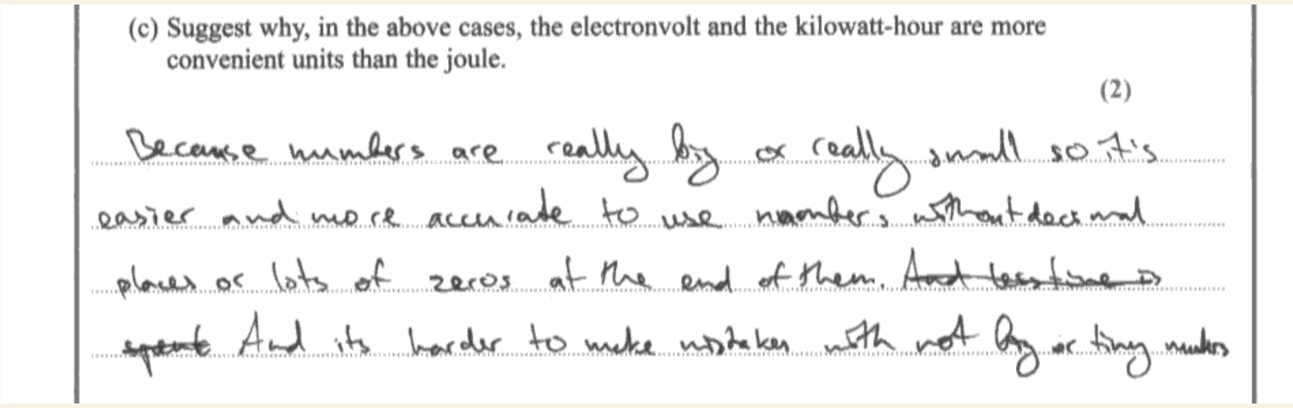
ResultsPlus

Examiner Comments

This candidate has correctly calculated the number of seconds in 8 hours, but has also applied the factor 8 to the power, probably because 8 appears twice in the question.

Question 19c

Somewhat under half of the entry got a mark for this, some of them extending it to a second mark. Very few chose to relate the convenience to the origin of the unit. Many described large and small quantities, but didn't always make it clear they were comparing to Joules, and often just said things like 'very big' or 'very small' without stating the unit to which they were referring.



(c) Suggest why, in the above cases, the electronvolt and the kilowatt-hour are more convenient units than the joule.

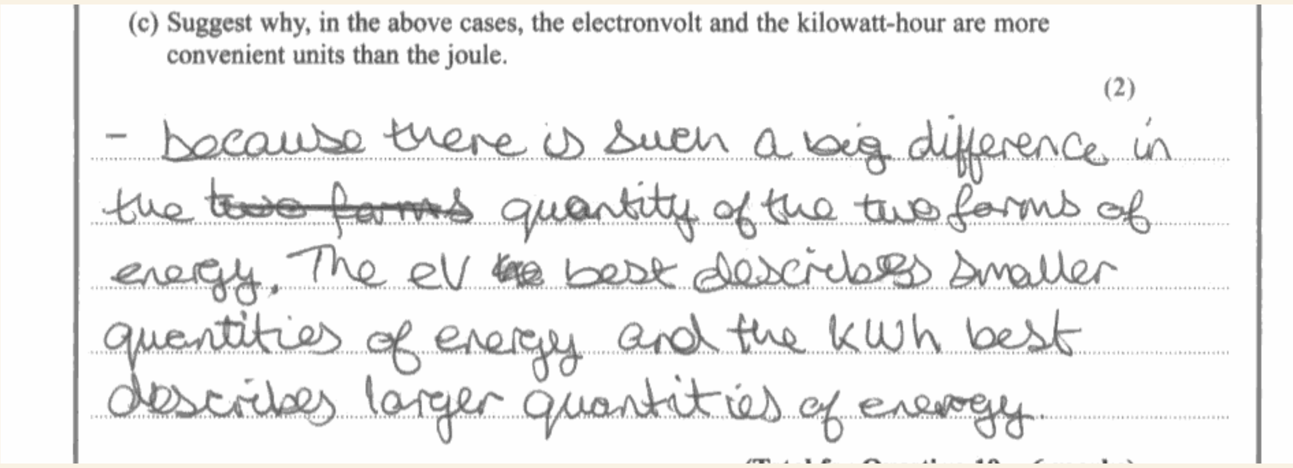
(2)

Because numbers are really big or really small so it's easier and more accurate to use numbers without decimal places or lots of zeros at the end of them. ~~And less time is spent~~ And its harder to make mistakes with not big or tiny numbers

ResultsPlus
Examiner Comments

While this candidate appreciates the relevance to this context of 'really big' or 'really small' numbers, it has not been made clear which refers to eV and which to kWh. If it is not stated, the term 'respectively' will be applied. As they are in the wrong order here with respect to the question, it has to be assumed that the references are incorrect.

In addition, it is not specified that it is the values in joules which are 'really big or really small'.



(c) Suggest why, in the above cases, the electronvolt and the kilowatt-hour are more convenient units than the joule.

(2)

- because there is such a big difference in the ~~two forms~~ quantity of the two forms of energy. The eV ~~the~~ best describes smaller quantities of energy and the kWh best describes larger quantities of energy.

ResultsPlus
Examiner Comments

This response identifies eV and kWh as referring to small and large quantities respectively, but the question asks about the joule specifically and it is not mentioned in the answer.

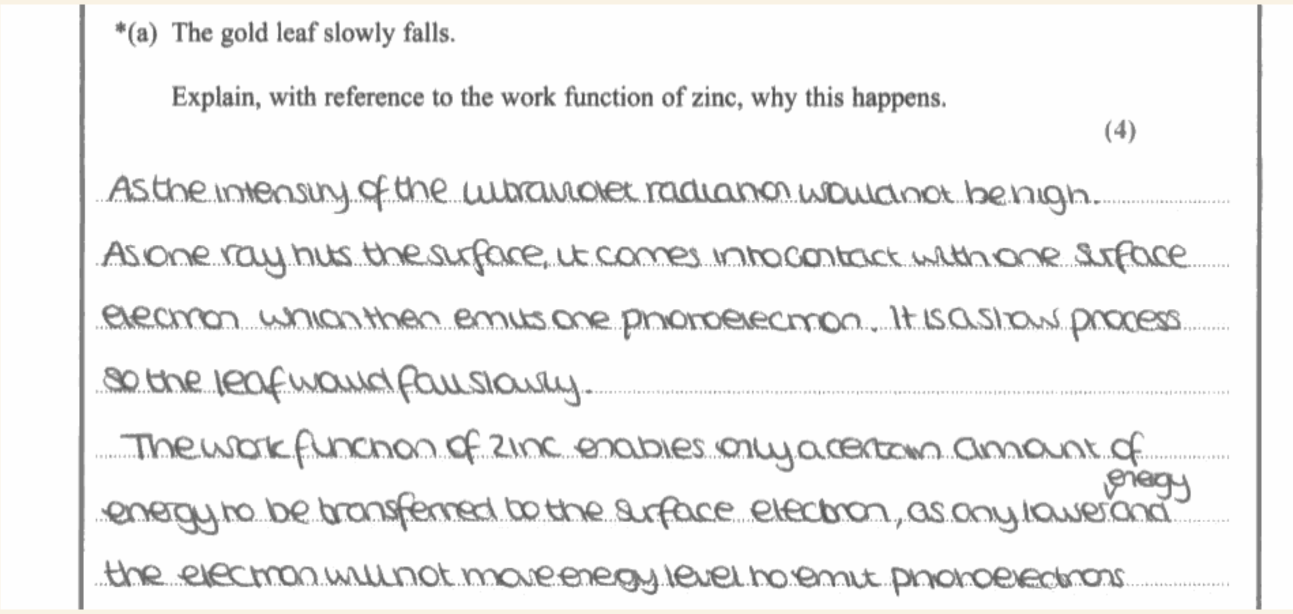
Question 20a

There was a bit of confusion with spectra here, with some mixing up of electrons and photons, but not to the extent seen in question 15.

The majority scored at least one mark for the emission of an electron and also picked up a second mark for either relevant reference to photons or describing why the leaf falls after electrons are lost.

A surprising number made no reference to photons at all, so they were unable to get a mark for the work function. Most at least attempted to refer to the work function as instructed by the question, although a few omitted it. Work function was sometimes described incorrectly in relation to threshold frequency, or just said that UV radiation has more energy than the work function or enough energy to overcome the work function – both without reference to photon energy, which is really the point of this topic for AS students. Some attempted to use the equation, but they didn't always identify the parts correctly.

With respect to the charge on the electroscope, some thought the photons carried charge, sometimes negative and sometimes positive, and some thought that the emission of electrons produced a positive charge which attracted the gold leaf.



*(a) The gold leaf slowly falls.

Explain, with reference to the work function of zinc, why this happens.

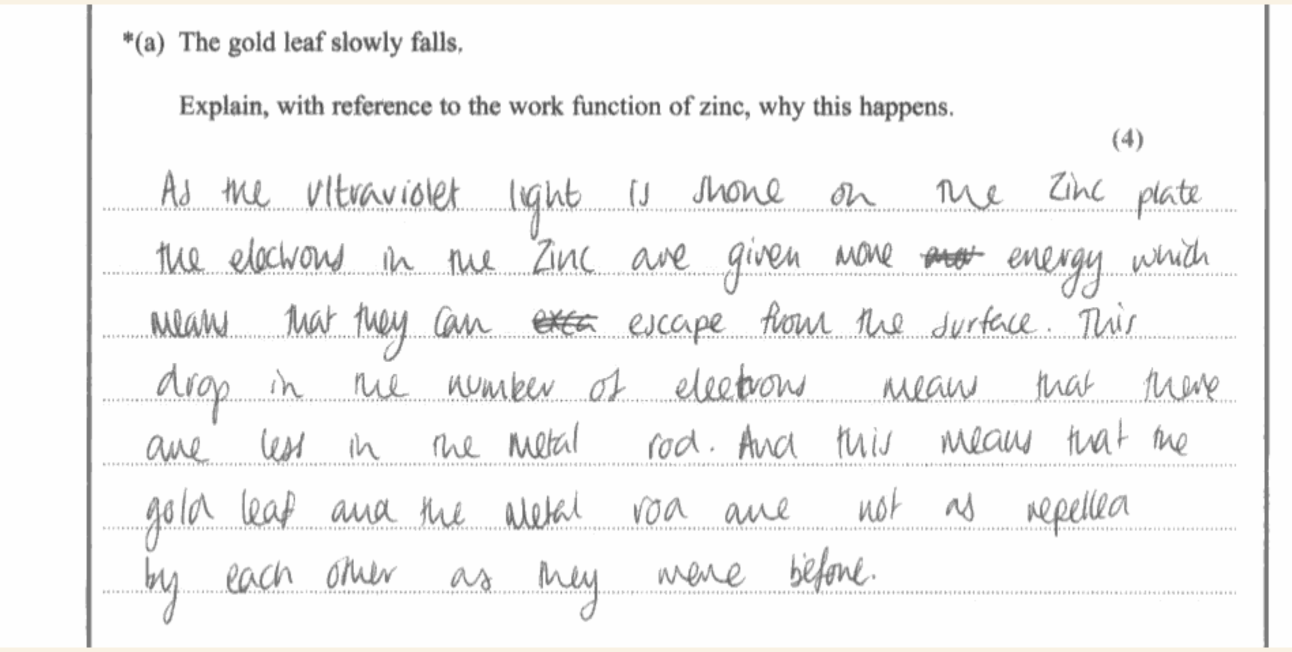
(4)

As the intensity of the ultraviolet radiation would not be high.
As one ray hits the surface, it comes into contact with one surface electron which then emits one photoelectron. It is a slow process so the leaf would fall slowly.
The work function of zinc enables only a certain amount of energy to be transferred to the surface electron, as any lower energy and the electron will not move energy level to emit photoelectrons

ResultsPlus
Examiner Comments

This answer shows identifiable signs of familiarity with the underlying principles of the photoelectric effect, but only gets credit for saying a photoelectron is emitted. The answer lacks clarity of expression and the precise use of technical terminology.

It refers to a ray rather than a photon. A single electron is said to be emitted, but this does not account for the leaf falling. The section about the work function is essentially correct, but it is not related specifically to photon energy.



*(a) The gold leaf slowly falls.

Explain, with reference to the work function of zinc, why this happens.

(4)

As the ultraviolet light is shone on the Zinc plate the electrons in the Zinc are given more ~~mor~~ energy which means that they can ~~exc~~ escape from the surface. This drop in the number of electrons means that there are less in the metal rod. And this means that the gold leaf and the metal rod are not as repelled by each other as they were before.

ResultsPlus

Examiner Comments

The loss of electrons and falling leaf are adequately covered here, but there is no reference to the work function despite the clear instruction in the question.

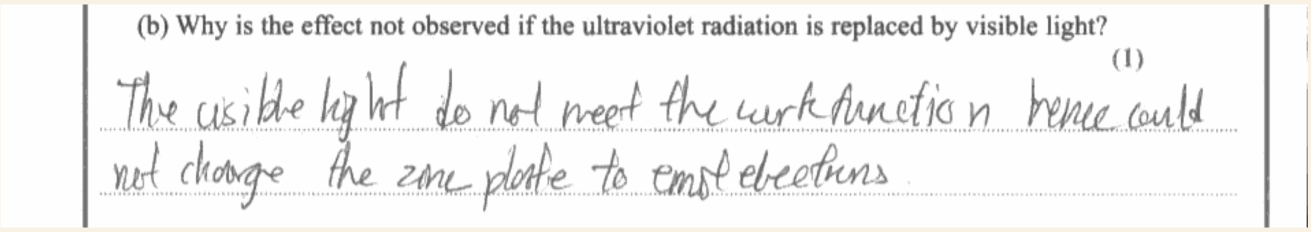
ResultsPlus

Examiner Tip

Be sure to address all parts required by the question.

Question 20b

A large majority got the mark here, by a correct reference to photons and work function or to threshold frequency. Those who didn't sometimes omitted reference to photons, speaking just of the energy of UV light, some said the threshold frequency was greater than the work function, and some just said visible light has less energy than UV radiation.



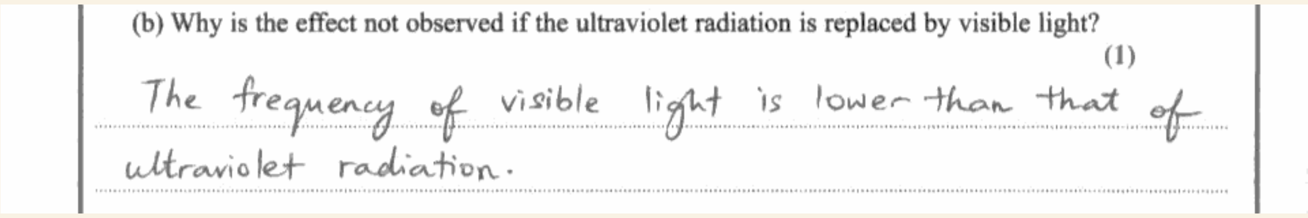
(b) Why is the effect not observed if the ultraviolet radiation is replaced by visible light?

(1)

The visible light do not meet the work function hence could not charge the zinc plate to emit electrons

Examiner Comments

This just refers to the light not meeting the work function. It needs to compare the work function energy to the energy of the photon.



(b) Why is the effect not observed if the ultraviolet radiation is replaced by visible light?

(1)

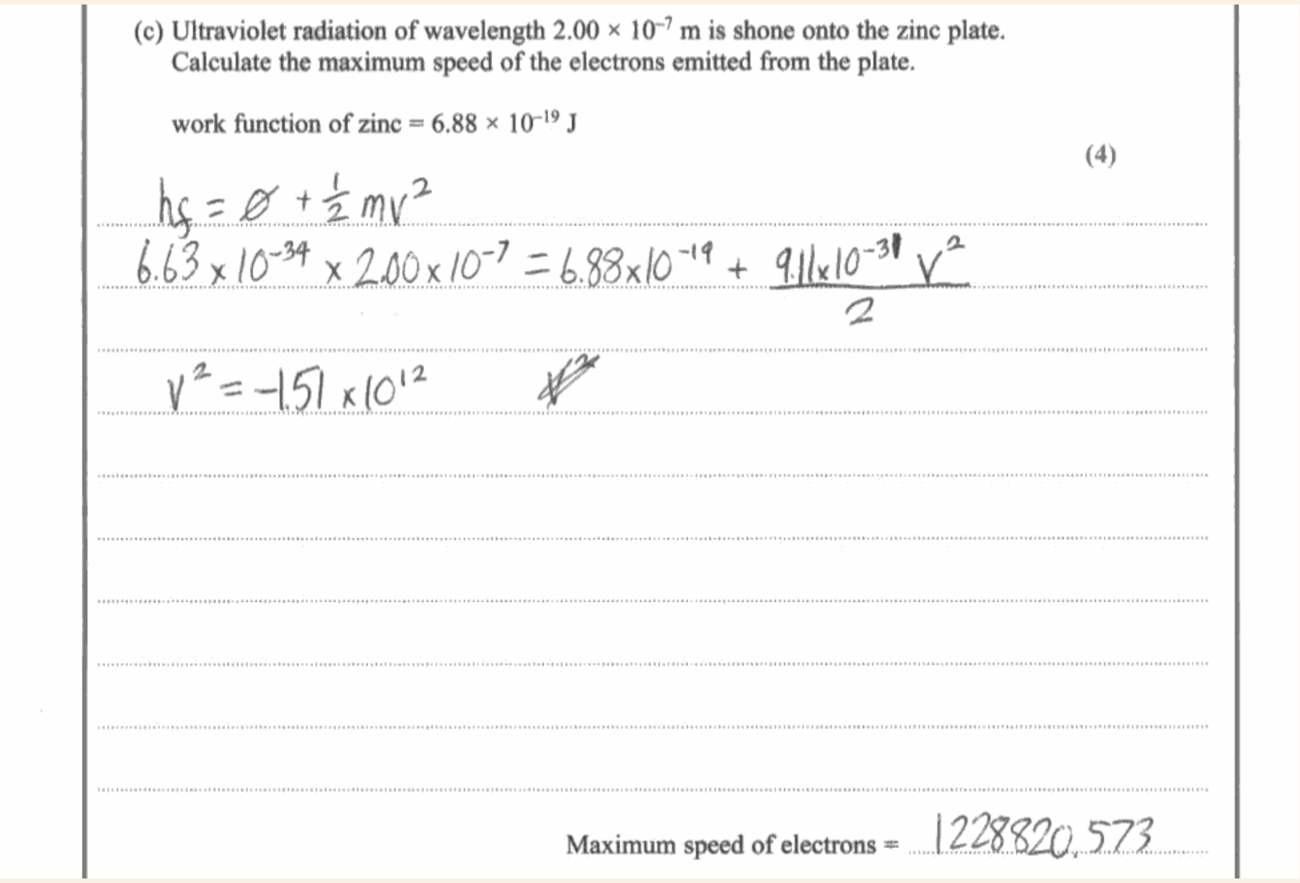
The frequency of visible light is lower than that of ultraviolet radiation.

Examiner Comments

It is not sufficient to compare the frequency of visible light to that of ultraviolet radiation as that does not, in itself, mean that visible light will not work. The relevant comparison is with the threshold frequency.

Question 20c

Half of the responses to this question were fully correct and a tenth missed one mark for completing the calculation to get the required answer. Sometimes this was for forgetting to find the square root. Some only got as far as the kinetic energy and a number failed to start by using the wavelength to find photon energy, either via the frequency or directly. A number of candidates substituted all the values into the photoelectric equation directly, but sometimes failed to get the final answer through making a mistake with the rearrangement. Candidates who set out their answers clearly in stages generally had little difficulty.



(c) Ultraviolet radiation of wavelength 2.00×10^{-7} m is shone onto the zinc plate.
Calculate the maximum speed of the electrons emitted from the plate.

work function of zinc = 6.88×10^{-19} J

(4)

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

$6.63 \times 10^{-34} \times 2.00 \times 10^{-7} = 6.88 \times 10^{-19} + \frac{9.11 \times 10^{-31} v^2}{2}$

$v^2 = -1.51 \times 10^{12}$

Maximum speed of electrons = 1228820.573

ResultsPlus

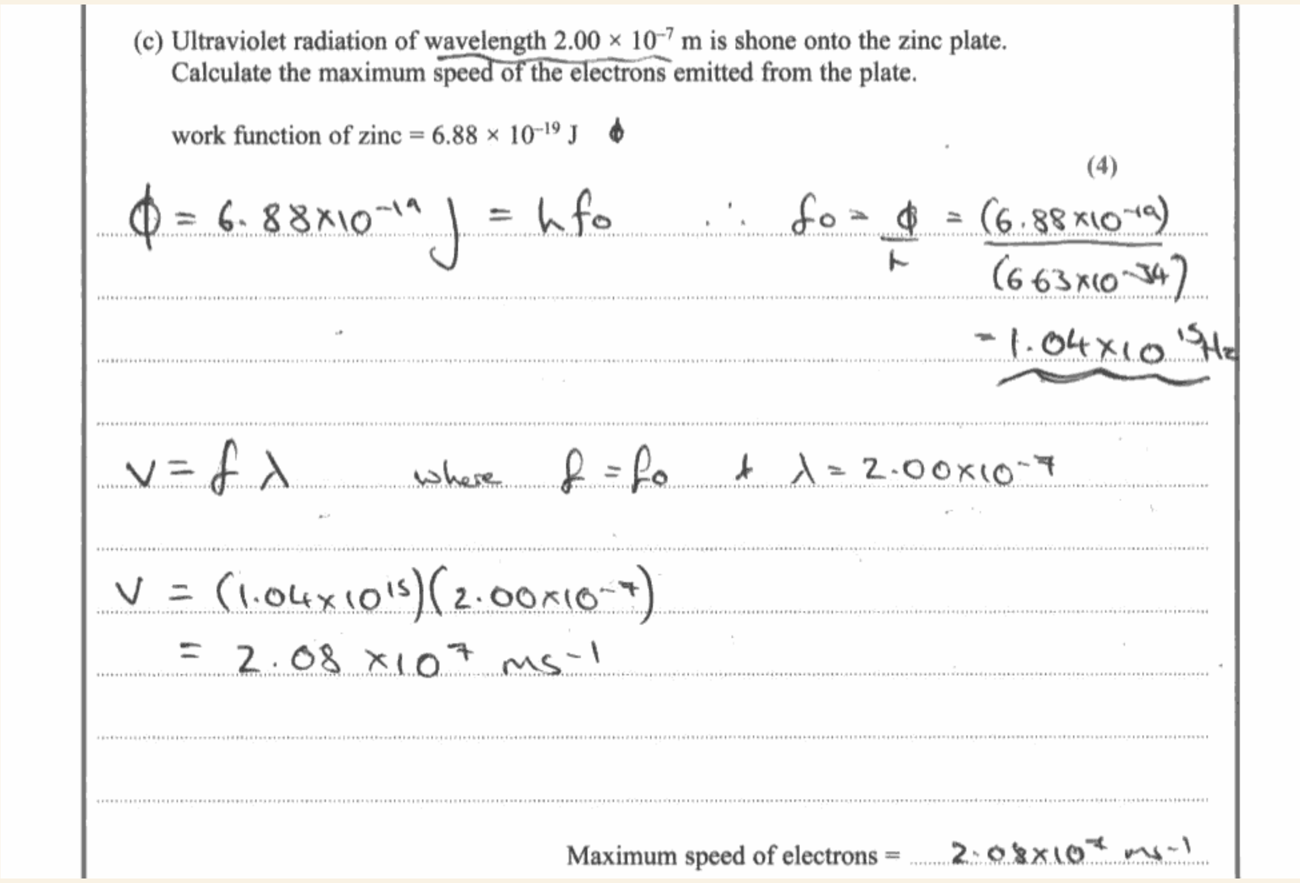
Examiner Comments

Although the correct equation has been selected, the value of wavelength has been substituted for *f* instead of frequency being calculated from wavelength. This gives a negative value for v^2, which ought to have rung alarm bells for the candidate, but this has been ignored in calculating a square root.

ResultsPlus

Examiner Tip

Unexpected results of calculations, such as the square root of a negative number or a velocity greater than the speed of light, are probably due to errors and should be checked rather than ignored.



(c) Ultraviolet radiation of wavelength 2.00×10^{-7} m is shone onto the zinc plate. Calculate the maximum speed of the electrons emitted from the plate.

work function of zinc = 6.88×10^{-19} J ϕ

(4)

$\phi = 6.88\times10^{-19}\,J = hf_0$ ∴ $f_0 = \frac{\phi}{h} = \frac{(6.88\times10^{-19})}{(6.63\times10^{-34})}$

$= 1.04\times10^{15}\,Hz$

$v = f\lambda$ where $f = f_0$ & $\lambda = 2.00\times10^{-7}$

$v = (1.04\times10^{15})(2.00\times10^{-7})$

$= 2.08\times10^{7}\,ms^{-1}$

Maximum speed of electrons = $2.08\times10^{7}\,ms^{-1}$

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Examiner Comments

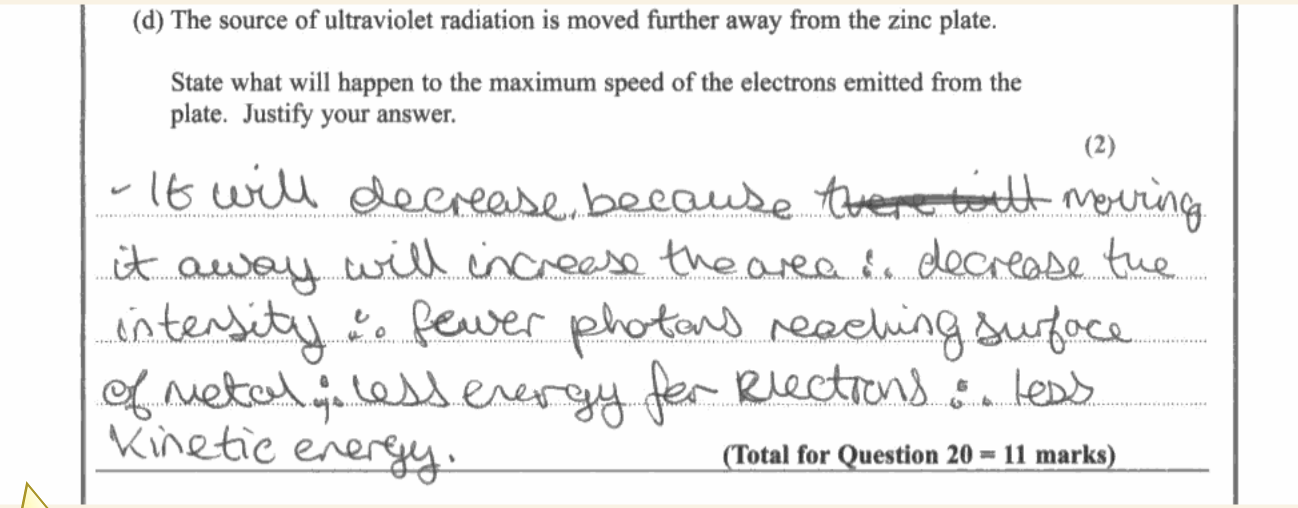
This candidate has used the work function to calculate the threshold frequency and then used this with wavelength in the wavespeed equation to get a spurious value of speed.

This is an example of selecting equations which have matching quantities to arrive at an answer with the correct name and dimensions but which has no contextual relationship to the correct quantity. Although *v* in this equation does represent a speed, it is the speed of a wave and not an electron. Similarly, the wavelength of a particular radiation has been matched to the frequency of a different wavelength - that of photons with energy matching the work function.

Question 20d

About two thirds of the candidates correctly stated that there would be no change, but only a quarter of them said why correctly. Some just referred to the photoelectric equation, saying that distance was not a factor in it. Many did not refer to photons, just commenting on the energy of the radiation.

Candidates suggesting a change usually chose a decrease in electron speed, often linking it to intensity – again missing the point of a central aspect of the photoelectric effect. Some misread the question and thought the Doppler effect was a factor, reducing energy through an increased wavelength.



(d) The source of ultraviolet radiation is moved further away from the zinc plate.

State what will happen to the maximum speed of the electrons emitted from the plate. Justify your answer.

(2)

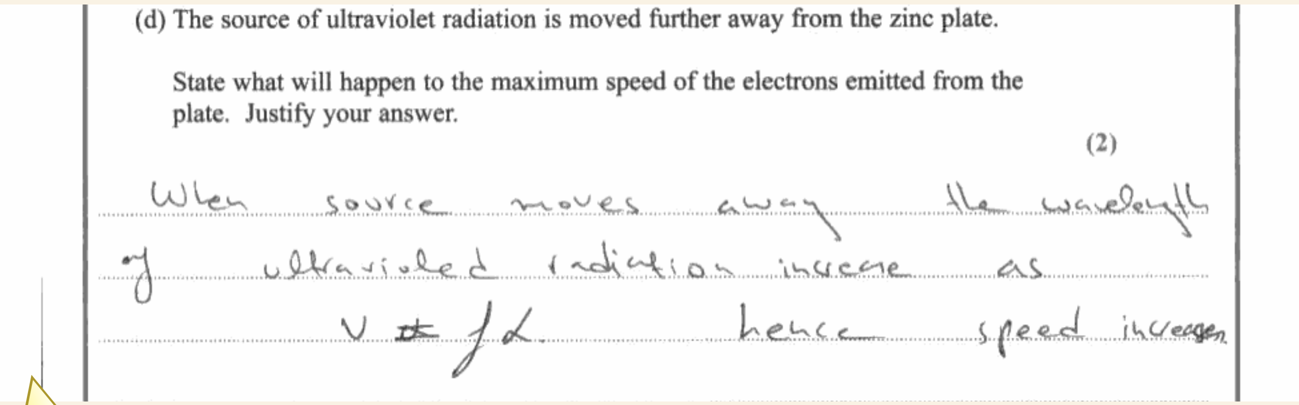
- It will decrease, because ~~there will~~ moving it away will increase the area ∴ decrease the intensity ∴ fewer photons reaching surface of metal ∴ less energy for electrons ∴ less kinetic energy.

(Total for Question 20 = 11 marks)

ResultsPlus

Examiner Comments

This sample is very well set out and shows a logical structure leading to its conclusion, despite it being quite incorrect. This is a good example of the reasoning expected by Classical Physics, but the candidate has missed the point that this is not what is observed and that, since Einstein's 1905 paper, we explain the effect in terms of photons.



(d) The source of ultraviolet radiation is moved further away from the zinc plate.

State what will happen to the maximum speed of the electrons emitted from the plate. Justify your answer.

(2)

When source moves away the wavelength of ultraviolet radiation increase as $v = f\lambda$ hence speed increases

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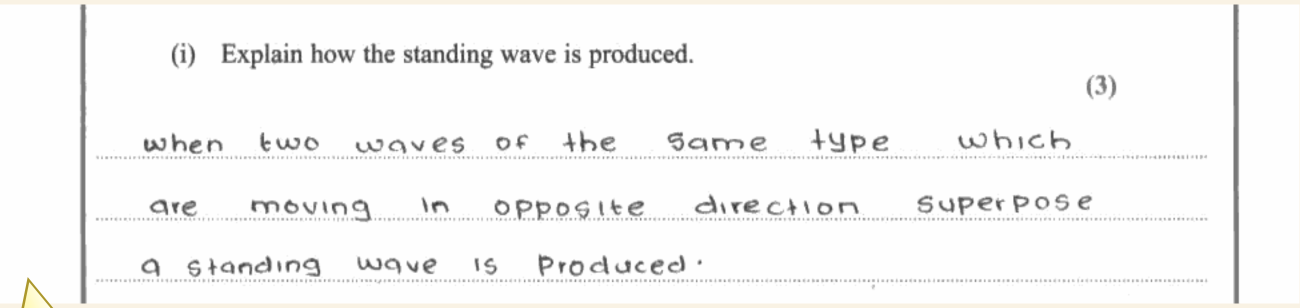
Examiner Comments

Some candidates misinterpreted 'moved further away' and thought the Doppler effect would occur. This candidate has compounded this error by using the increased wavelength which would be produced and to deduce a greater velocity for the radiation and then taking that to be the velocity of the electrons.

Question 21a

Nearly half got 3 marks and the median mark was 2. The most common missing mark by far was the unit for tension, which was surprising when this is a known quantity and mass per unit length had to be deduced from its name. Some students might benefit from practice in deriving quantities from equations on the data sheet.



(i) Explain how the standing wave is produced.

(3)

when two waves of the same type which are moving in opposite direction superpose a standing wave is produced.

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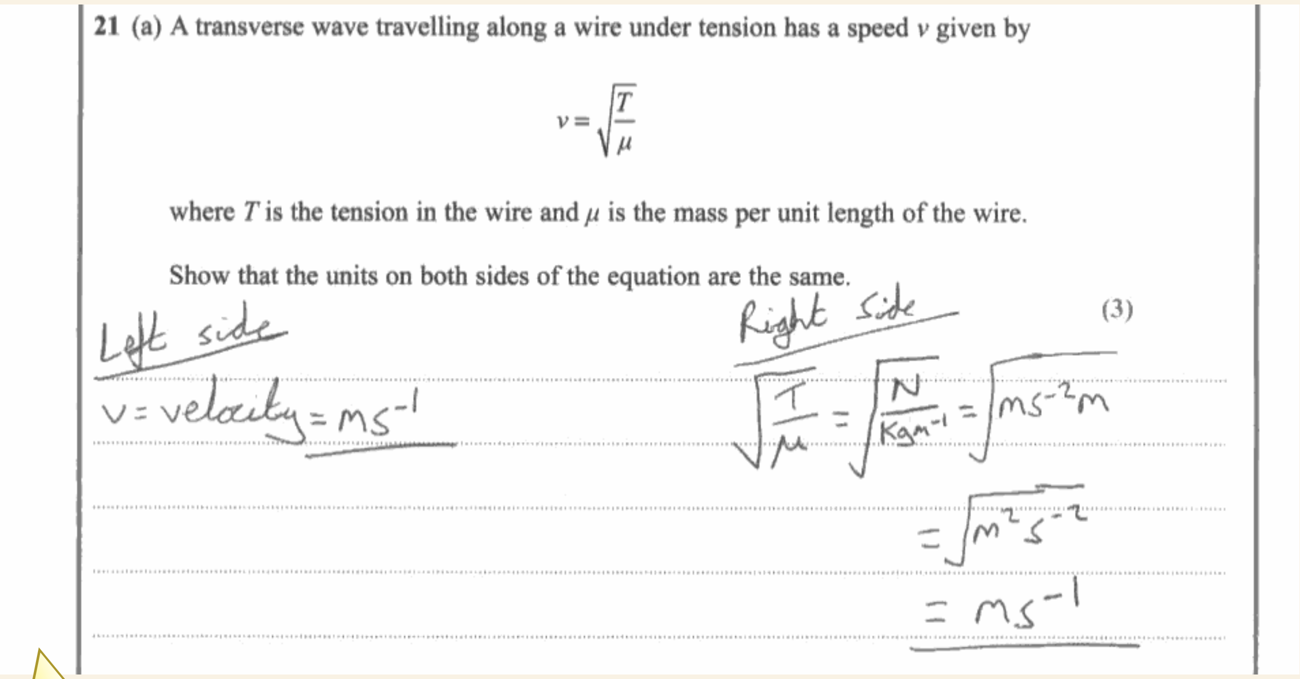
Examiner Comments

This was a fairly common response where candidates were able to deduce the new unit of mass per unit length from its description, but could not give the base units for newton. One way to get the base units for a derived unit is to use an equation and substitute the known units, for example *F* = *ma* from the data sheet.



21 (a) A transverse wave travelling along a wire under tension has a speed v given by

$$v = \sqrt{\frac{T}{\mu}}$$

where T is the tension in the wire and μ is the mass per unit length of the wire.

Show that the units on both sides of the equation are the same.

(3)

Left side

$v = \text{velocity} = ms^{-1}$

Right side

$\sqrt{\frac{T}{\mu}} = \sqrt{\frac{N}{Kgm^{-1}}} = \sqrt{ms^{-2}m}$

$= \sqrt{m^2 s^{-2}}$

$= ms^{-1}$

ResultsPlus

Examiner Comments

The correct answer is derived here, but it does not exactly fulfil the instruction to 'show that' it is correct because the units for N are not given, so a step is missed.

ResultsPlus

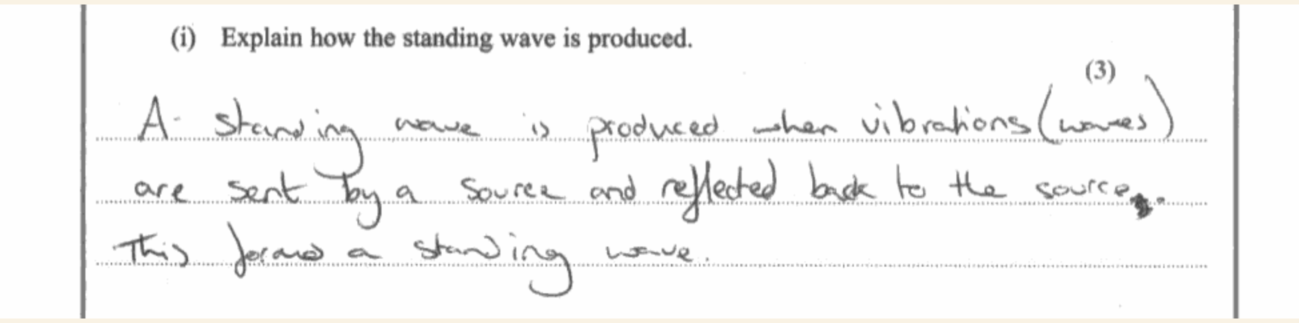
Examiner Tip

When you are asked to 'show that' something is so you must include all the relevant steps in your answer.

Question 21bi

Half of the candidates picked up at least 2 marks here, and the great majority at least 1 mark. Each of the three relevant points was seen to be missing in some responses, but reflected waves were mentioned most frequently. The third mark was awarded most often for mention of nodes and antinodes. A fair proportion referred to waves superimposing, which is not accepted.

This is another standard ‘set piece’ answer which can be learned and applied to many situations – most of which will use the same core mark scheme once the nature of the superposing waves has been established from the context.



(i) Explain how the standing wave is produced.

(3)

A standing wave is produced when vibrations (waves) are sent by a source and reflected back to the source. This forms a standing wave.

ResultsPlus

Examiner Comments

This only gets one mark for mentioning the reflected wave. This question is often asked and candidates should learn the standard response. It should also be plain that there are three marks, so three points will be needed for an answer. This candidate may have thought they had three points - waves sent, waves reflected, standing wave produced - but just repeating the question will never be one of the three points for an answer.

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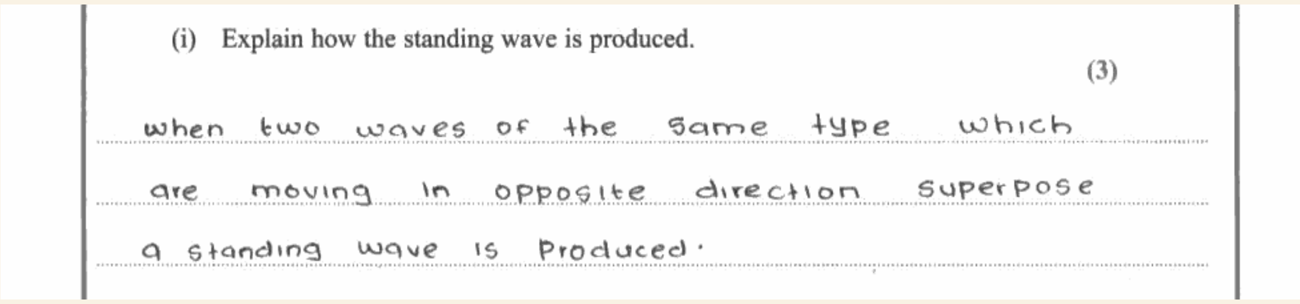
Examiner Tip

If an explanation is worth three marks you should be sure to include at least three clear and separate points in your answer.



(i) Explain how the standing wave is produced.

(3)

when two waves of the same type which are moving in opposite direction superpose a standing wave is produced.

ResultsPlus

Examiner Comments

This answer gets two marks for the two waves and use of 'superpose', but fails to mention any of the features of a standing wave caused by superposition for the third mark.

ResultsPlus

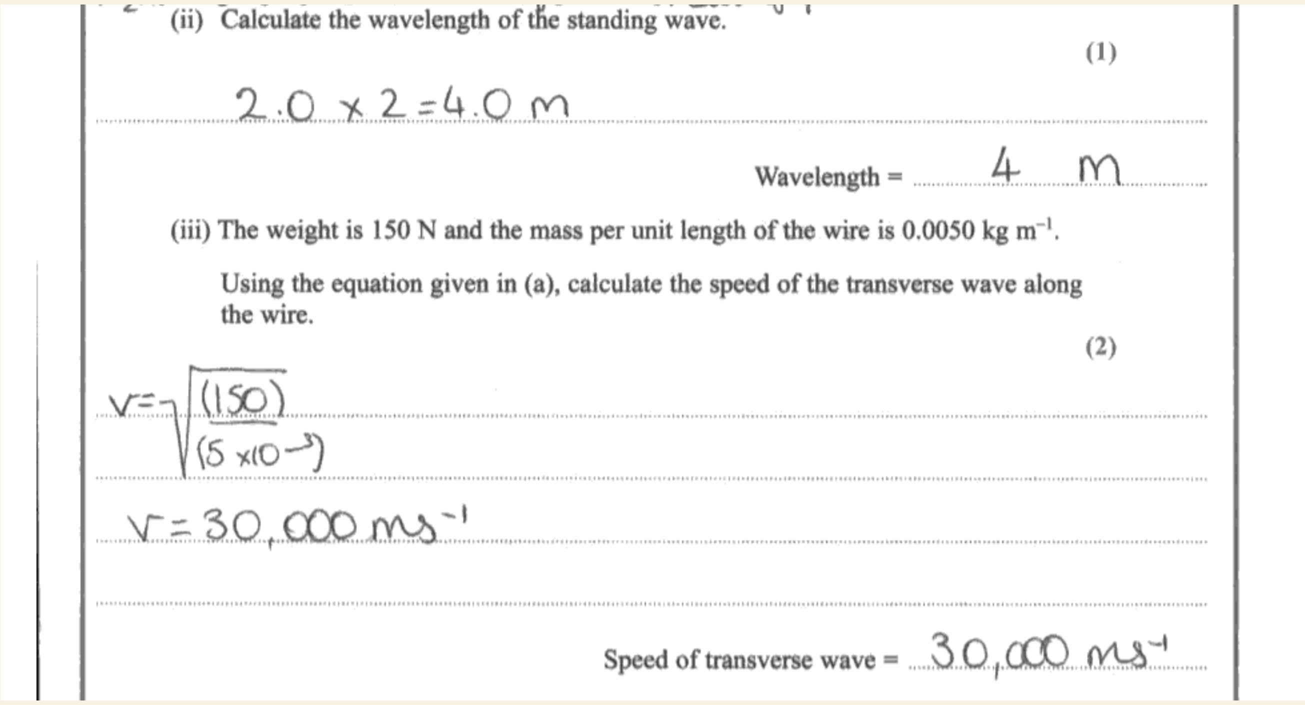
Examiner Tip

Learn the standard definitions and descriptions which occur frequently so you can apply them easily to the required context.

Question 21bii-iii

21 (b) (ii) A good proportion could state the wavelength, but 2 m and 1 m were seen fairly often. A number of answers referred directly to , e.g. 2.

21(b) (iii) This presented few difficulties in general, but the most common errors were neglecting the square root and multiplying the weight value by *g*, mistaking the value stated as weight for mass in order to attempt to calculate weight. Candidates occasionally divided weight by *g*.



(ii) Calculate the wavelength of the standing wave.

(1)

$2.0 \times 2 = 4.0$ m

Wavelength = 4 m

(iii) The weight is 150 N and the mass per unit length of the wire is 0.0050 kg m^{-1}.

Using the equation given in (a), calculate the speed of the transverse wave along the wire.

(2)

$v = \sqrt{\frac{(150)}{(5 \times 10^{-3})}}$

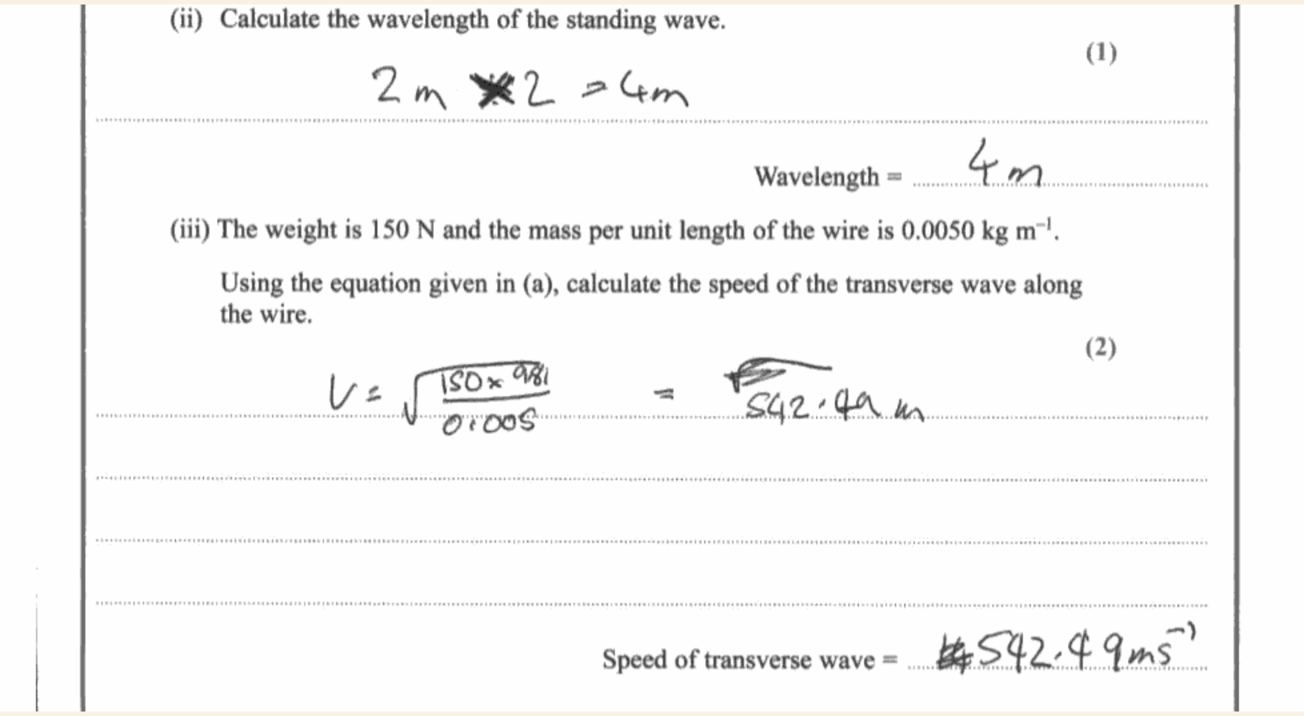
$v = 30{,}000$ ms^{-1}

Speed of transverse wave = 30,000 ms^{-1}

ResultsPlus

Examiner Comments

Candidates sometimes forgot the square root.



(ii) Calculate the wavelength of the standing wave.

(1)

2m ×2 = 4m

Wavelength = 4m

(iii) The weight is 150 N and the mass per unit length of the wire is 0.0050 kg m^{-1}.

Using the equation given in (a), calculate the speed of the transverse wave along the wire.

(2)

$v = \sqrt{\frac{150 \times 9.81}{0.005}} = 542.49\,m$

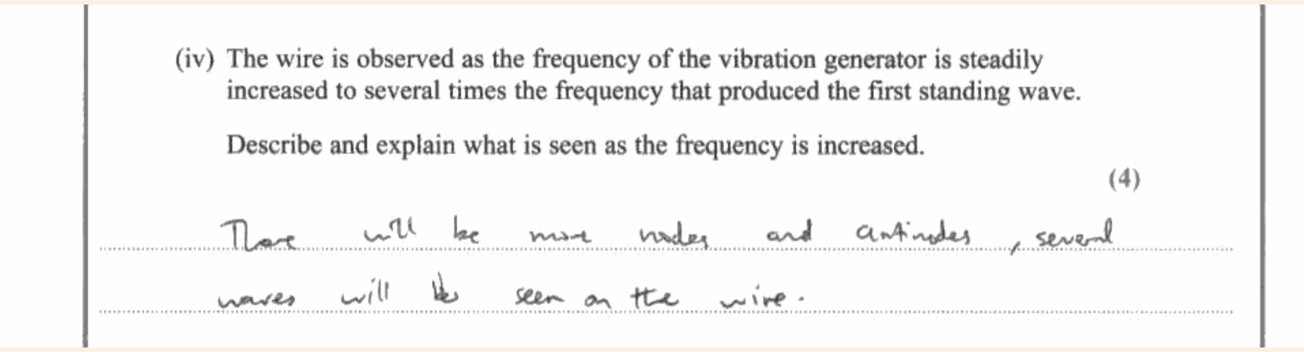
Speed of transverse wave = 542.49 ms^{-1}

Examiner Comments

Although they were given the weight in newton, some candidates still multiplied this value by *g*, as if they were calculating *W* = *mg.*

Question 21biv

Most candidates were able to get a first mark, often for suggesting that more nodes, antinodes or 'loops' would be seen, although they sometimes lost this by describing it as more standing waves on the string. About half also got a second mark, for decreasing wavelength, suggesting frequencies at which no effect is seen or diagrams showing a sequence. The constant wavespeed was not often mentioned, even by those who must have assumed it to deduce a shorter wavelength, despite it being given at the start of the question. About a fifth got 3 marks, but 4 were very rarely awarded. Some responses dealt in some detail, including diagrams, with the sequence of patterns seen, suggesting that they had seen the experiment suggested in the specification. To others this appeared to be a novel application. Some of the diagrams provided were of more use than others, particularly as quite a few showed a constant wavelength and an increasing length of wire to accommodate the extra 'loops', but even when they didn't gain direct credit they probably helped candidates to visualise the situation and get some of the marks.



(iv) The wire is observed as the frequency of the vibration generator is steadily increased to several times the frequency that produced the first standing wave.

Describe and explain what is seen as the frequency is increased.

(4)

There will be more nodes and antinodes , several waves will be seen on the wire.

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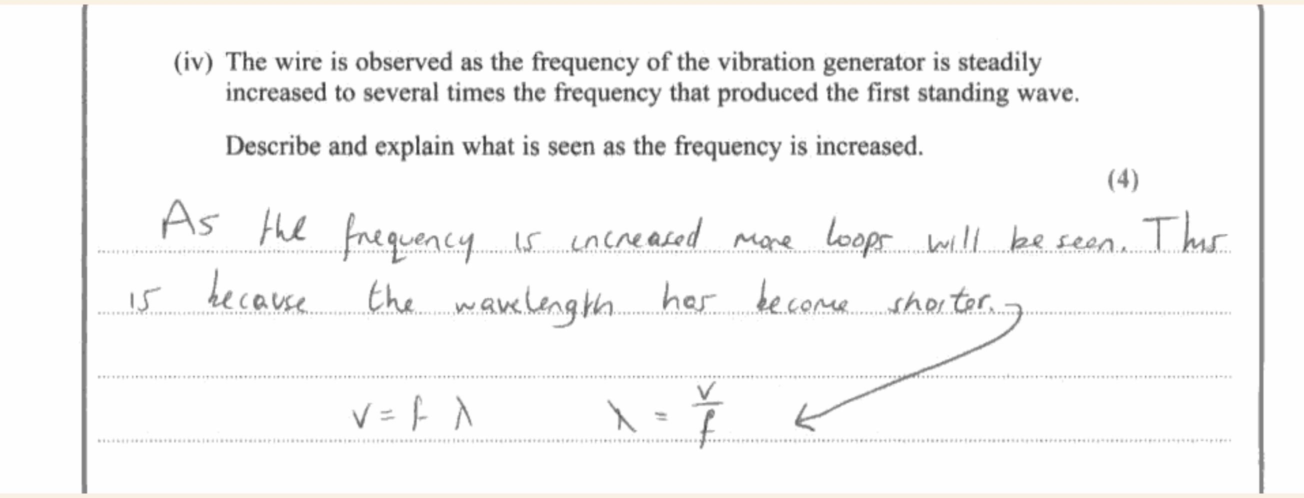
Examiner Comments

The question asks candidates to 'describe and explain', but this response only includes a description.

ResultsPlus

Examiner Tip

Carefully note the command words, such as 'describe' and 'explain', in the question and be sure to work to the required level in your response. When you need to explain you must give a reason why something happens, not just say what happens. Even if you don't use the words specifically, think whether 'because' or 'so' could link the reason and the description.



(iv) The wire is observed as the frequency of the vibration generator is steadily increased to several times the frequency that produced the first standing wave.

Describe and explain what is seen as the frequency is increased.

(4)

As the frequency is increased more loops will be seen. This is because the wavelength has become shorter.

$v = f\lambda \qquad \lambda = \frac{v}{f}$

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Examiner Comments

This describes one observation and explains it appropriately, but clearly only includes two points. Although it is implicit in the equation shown, the candidate did not state that speed is constant, for example, and there was more to say about the observed patterns.

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Examiner Tip

In descriptive answers, consider whether you can identify a distinct point for each mark being given.

Paper Summary

Candidates should identify standard situations, such as standing waves, atomic spectra, photoelectric effect and effect of temperature on resistance, which occur frequently and require very similar descriptions and explanations with only slight variations for context. While taking careful note of the context so as not to answer a question from the previous paper instead of the current one, they should prepare ‘set piece’ answers. Candidates should take note of the available marks for a question and be sure they have made a sufficient number of feasibly creditworthy responses in their answer. The use of bullet points may help with this.

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