Pearson

Edexcel

Examiners' Report
June 2024

IAL Physics WPH12 01

ResultsPlus

Introduction

WPH12 is a unit paper on the Pearson Edexcel International AS level course which covers the topics of Waves and Electricity. As usual, the paper for this series contained 10 marks of multiple choice questions in Section A.

Section B had 7 longer answer questions which consisted of short open responses, calculations and some extended written answers. Question 14(b) was related to Core Practical activities that candidates undertake as part of the IAL course. This unit always contains one 6 mark linkage question, which on this occasion was about how atoms in a gas can be stimulated to release photons.

On the whole, candidate performance on the paper during this series was broadly in line with previous series, although there are always going to be particular questions that candidates find more challenging. In this series the questions found to be the most difficult were Q13(b), Q13(c), Q14(a)(ii), Q15(b), Q17(b) Q18(c)(i) and Q18(c)(ii).

Candidates continue to show evidence of good preparation for the test but there are some aspects that need more focus. In many cases marks were lost for failing to add units to calculations and some responses were too general and not linked to the context in the question.

The standard in this paper was similar to previous series although there were several contexts within this paper that may have been less familiar than previous series, for example questions 18 and 15.

Calculations were generally performed well but there are still some responses to longer questions where application of physics principles was lacking.

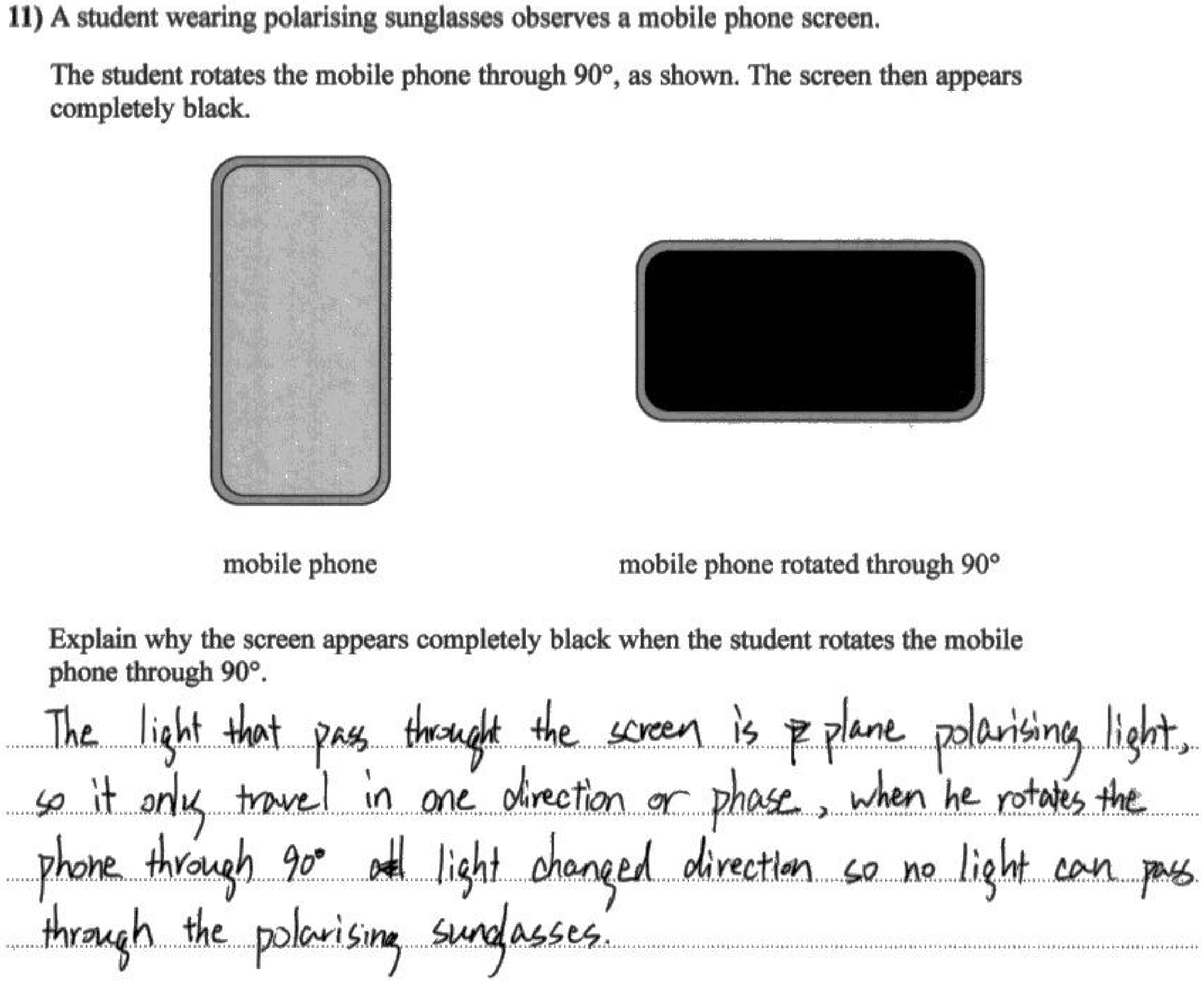
Section A: Multiple Choice

Although Section A was generally completed very well by most candidates, questions 2 and 8 were answered correctly by less than half the candidates.

	Subject	Correct response	Comment
1	Comparing resistance of a wire and thermistor when temperature increases	B	Temperature increase reduces thermistor resistance and increases wire resistance
2	Potential divider circuit	D	Potential difference is shared
3	Use of Snell's law	B	Correct rearrangement
4	Wave particle duality	C	All other responses relate to particle nature of light
5	Internal resistance	C	Use of $E = I(R + r)$
6	Photoelectric effect	C	Correct definition of threshold frequency
7	Resistors in series and parallel	D	Correct rearrangement of relevant formulae
8	Wave on a string under tension	C	Correct rearrangement of tension formula
9	Ohm' and Kirchoff's laws	A	Correct calculation and arrangement
10	Photoelectric effect	B	Correct gradient calculation linked to Einstein equation

Question 11

This was an interesting question in the sense that it had veered from the more expected format of a question involving polarisation. Many candidates failed to appreciate the importance of the context and simply regurgitated a definition of polarised and unpolarised light. It was important to understand that the mobile phone screen contains a liquid crystal display that does not emit light by itself but rather modulates light passing through it. The screen itself therefore lets polarised light pass through it. Most questions involving polarisation ask candidates to explain why light will or will not pass through polaroid filters in a more specific way. In this context there are two filters which at a certain point will have planes either perpendicular or parallel to each other.



11) A student wearing polarising sunglasses observes a mobile phone screen.

The student rotates the mobile phone through 90°, as shown. The screen then appears completely black.

mobile phone

mobile phone rotated through 90°

Explain why the screen appears completely black when the student rotates the mobile phone through 90°.

The light that pass through the screen is ~~p~~ plane polarising light, so it only travel in one direction or phase, when he rotates the phone through 90° ~~all~~ light changed direction so no light can pass through the polarising sunglasses.

ResultsPlus Examiner Comments

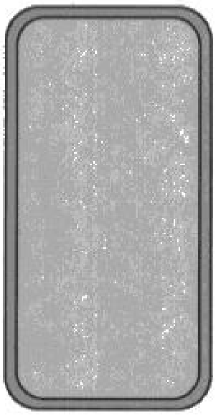
This candidate recognised that the light emitted from the mobile phone screen is plane polarised as the screen itself is having an effect on the orientation of the light passing through it. It was a promising start but an explanation of how the planes of polarisation would have an effect on the transmission of light passing through them upon rotation was not discussed in any detail, so marking point 2 was not scored. No light passing through the polarising sunglasses clearly scored marking point 3.

ResultsPlus Examiner Tip

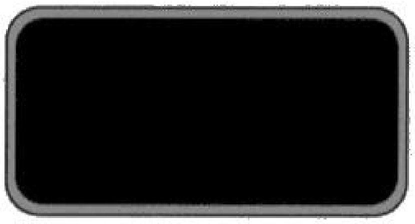
Polarisation occurs as a consequence of unpolarised light reflecting from a medium with a refractive index. It should be obvious that the light source from the phone was polarised when passing though the (liquid crystal) display. Try to describe the context you have been presented with rather than giving a learned definition of polarised or unpolarised light.

11) A student wearing polarising sunglasses observes a mobile phone screen.

The student rotates the mobile phone through 90°, as shown. The screen then appears completely black.



mobile phone



mobile phone rotated through 90°

Explain why the screen appears completely black when the student rotates the mobile phone through 90°.

When light passes through a polarising filter, it becomes polarised. This is when the electromagnetic waves that go in every direction are forced To go in one direction only. Rotating the phone through 90° and watching through ~~polarises the light rays~~ polarising ~~passes~~ sunglasses polarises the light until eventually rays going in every direction are eliminated, leaving darkness.

(Total for Question 11 = 3 marks)

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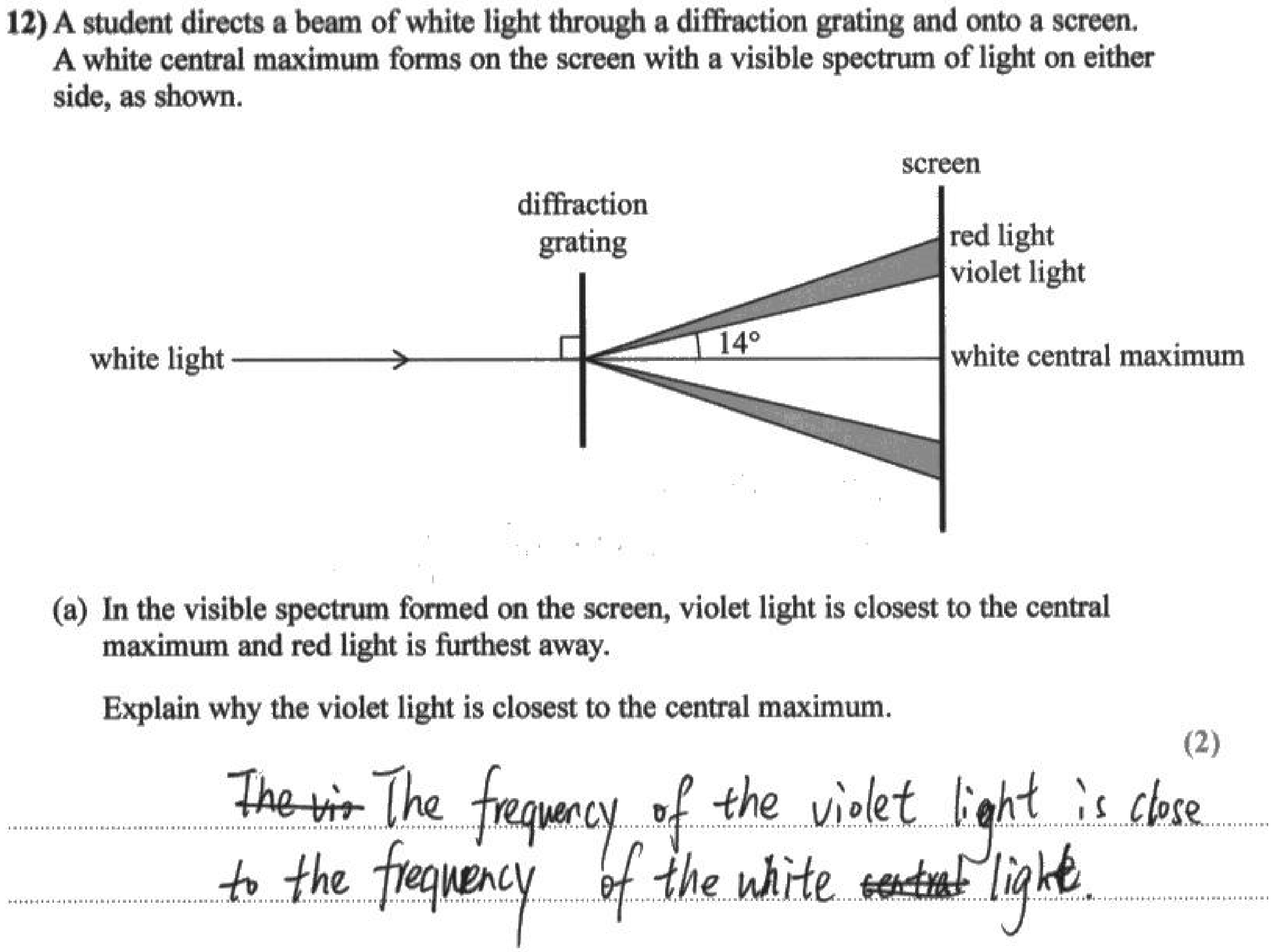
Examiner Comments

In this response the candidate was unsure as to why light transmitted from a mobile phone was originally seen by an observer wearing polarising sunglasses, but after rotation of the phone was not. There was a suggestion that that the sunglasses polarise the light but the light from the phone is already polarised before being observed. It was further suggested that the polarising filters would block light in every direction at some point, which is clearly non sensical.

Question 12 (a)

This question is a variation on a similar theme from previous series where candidates have been asked to explain what would be observed if white light was shone through a diffraction grating. In this context we are told that a white central maximum would be formed and the diagram displays the position of red and violet from the visible spectrum. The explanation for this is linked to the wavelength and the diffraction grating formula.



12) A student directs a beam of white light through a diffraction grating and onto a screen. A white central maximum forms on the screen with a visible spectrum of light on either side, as shown.

(a) In the visible spectrum formed on the screen, violet light is closest to the central maximum and red light is furthest away.

Explain why the violet light is closest to the central maximum.

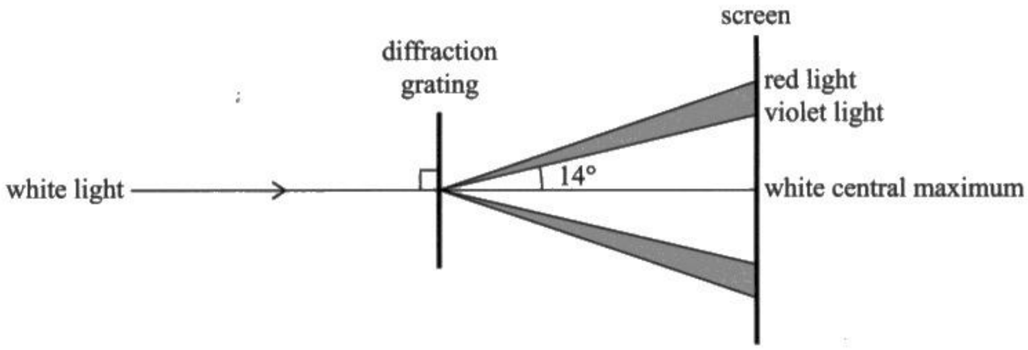
(2)

~~The vio~~ The frequency of the violet light is close to the frequency of the white ~~central~~ light.

ResultsPlus
Examiner Comments

In this example there is no reference at all to wavelength but rather a vague reference about frequency and no mention at all of a relevant formula. Statements such as one frequency being close to another would be unlikely to ever score anything. This script clearly scores 0 marks.

12, A student directs a beam of white light through a diffraction grating and onto a screen. A white central maximum forms on the screen with a visible spectrum of light on either side, as shown.



(a) In the visible spectrum formed on the screen, violet light is closest to the central maximum and red light is furthest away.

Explain why the violet light is closest to the central maximum.

(2)

Because it has the shortest wavelength, according to the diffraction grating formula, [illegible] $n\lambda = d\sin\theta$, as the wavelength decreases, the angle will decrease as they are directly proportional.

ResultsPlus
Examiner Comments

This response scores the first marking point for recognising that violet has a shorter wavelength than red. Although this has not been specifically stated it is clear from the wording in the question that the candidate is referring to violet and not red. The second marking point has not been awarded as although the formula has been written there is no clear link to d sinθ being smaller meaning θ must be smaller, nor a reference to sinθ being smaller.

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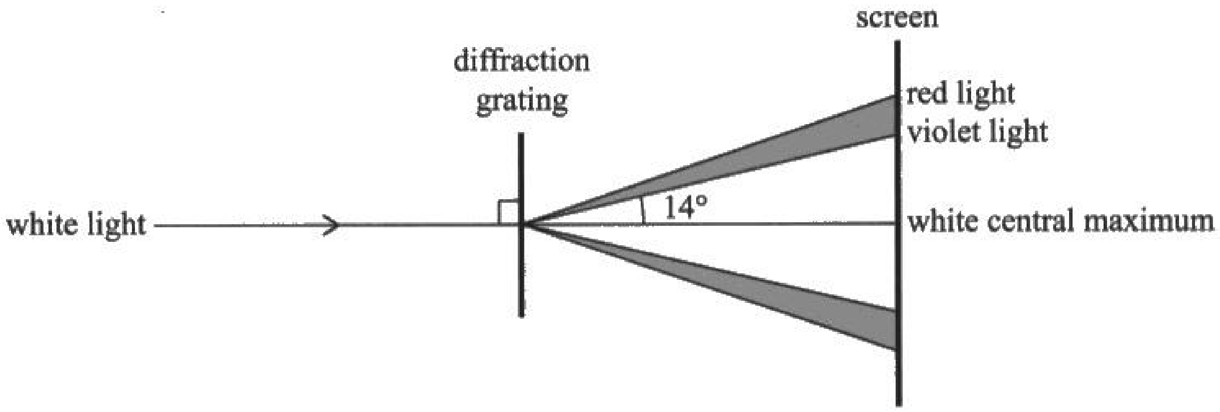
Examiner Tip

When explaining the behaviour of waves during diffraction it would always be helpful to use the formula nλ = dsinθ to explain how a change in angle affects the wavelength or vice versa.

12) A student directs a beam of white light through a diffraction grating and onto a screen. A white central maximum forms on the screen with a visible spectrum of light on either side, as shown.



(a) In the visible spectrum formed on the screen, violet light is closest to the central maximum and red light is furthest away.

Explain why the violet light is closest to the central maximum.

(2)

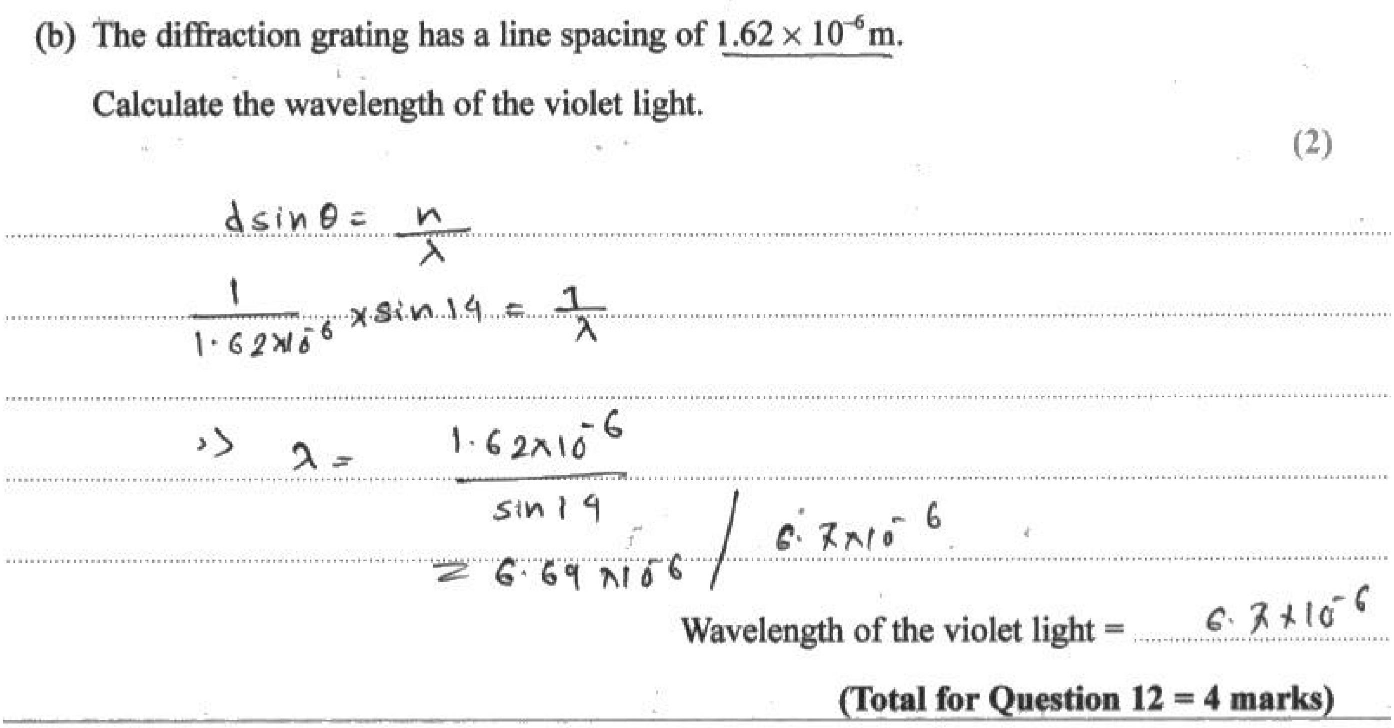
According to the formula $n\lambda = d\sin\theta$ · where d is constant and n is constant since order of difraction is under observation. we see $\lambda \propto \sin\theta$ then violet due to a lower wavelength of 400nm has lower $\sin\theta$ that is the violet light refracts by ~~a~~ smallest angle.

ResultsPlus
Examiner Comments

This was a rare two mark response where the candidate has clearly used the formula $n\lambda = d\sin\theta$ to explain that because violet has a shorter wavelength and both n and d are constant, then clearly $\sin\theta$ must be smaller for violet as it has a shorter wavelength.

Question 12 (b)

This was a straightforward calculation using the formula nλ = dsinθ. The required angle needed to be taken from the diagram and the line spacing was also supplied. It should have also been evident that the diagram was showing a first order diffraction pattern and therefore the value of n was 1. If any other value of n was used then only the first marking point could be awarded.



(b) The diffraction grating has a line spacing of 1.62×10^{-6} m.

Calculate the wavelength of the violet light.

(2)

$d\sin\theta = \frac{n}{\lambda}$

$\frac{1}{1.62 \times 10^{-6}} \times \sin 14 = \frac{1}{\lambda}$

$\Rightarrow \lambda = \frac{1.62 \times 10^{-6}}{\sin 14}$

$= 6.69 \times 10^{-6}$ / 6.7×10^{-6}

Wavelength of the violet light = 6.7×10^{-6}

(Total for Question 12 = 4 marks)

ResultsPlus
Examiner Comments

In this example the candidate clearly did not understand that d is the line spacing and this value was given, the candidate thought that the line spacing had to be calculated by taking the reciprocal of the value given. As a consequence neither mark could be awarded as the formula was not used correctly and the calculated value was incorrect. It is worth noting that no unit was written next to the calculated value.

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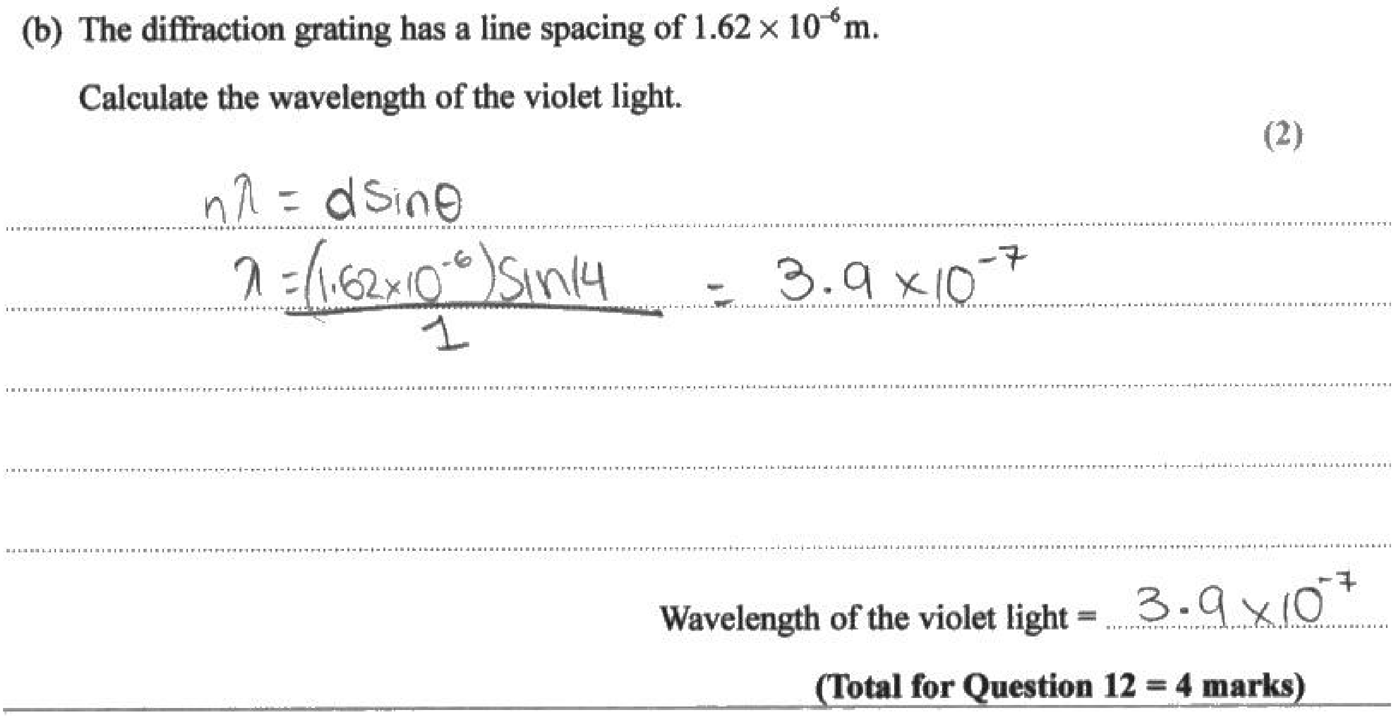
Examiner Tip

Make sure that you are aware of what each of the symbols in a formula represent.



(b) The diffraction grating has a line spacing of 1.62×10^{-6} m.

Calculate the wavelength of the violet light.

(2)

$n\lambda = d\sin\theta$

$\lambda = \frac{(1.62\times10^{-6})\sin 14}{1} = 3.9\times10^{-7}$

Wavelength of the violet light = 3.9×10^{-7}

(Total for Question 12 = 4 marks)

ResultsPlus
Examiner Comments

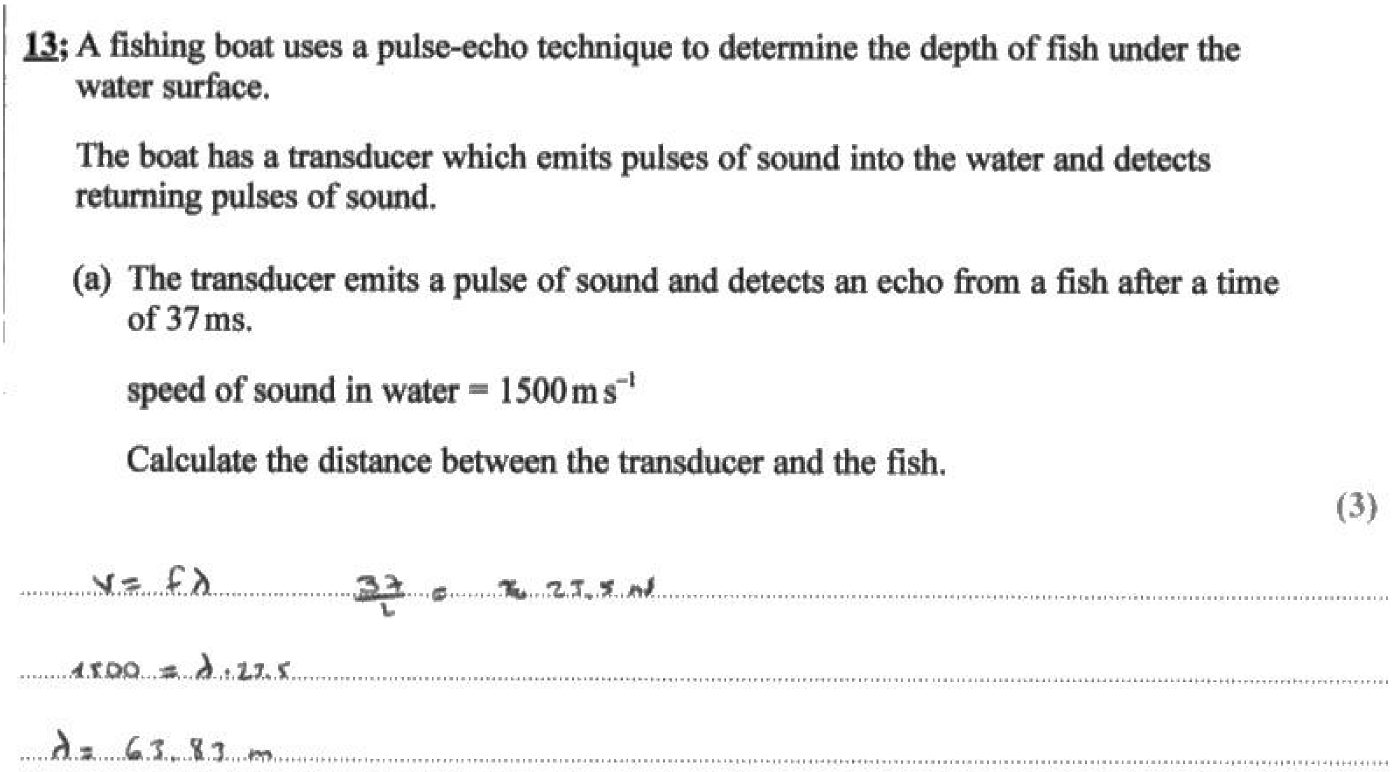
The formula was used to calculate the correct value for wavelength, however, as was all too common, this candidate failed to provide the unit for wavelength in the answer line.

ResultsPlus
Examiner Tip

Always provide a correct unit for any calculated quantity.

Question 13 (a)

This was quite a standard question involving the pulse echo technique where sound waves are being used to detect fish. The duration of the pulse was provided as well as the speed of sound in water. Candidates were required to use this information to calculate the distance to the fish. Successful candidates recognised that a correct calculation involved either doubling the time or halving the distance and substituting these into the equation v = s/t. This was a well answered question and indicates that candidates have become more familiar with the applications of the pulse echo technique.



13; A fishing boat uses a pulse-echo technique to determine the depth of fish under the water surface.

The boat has a transducer which emits pulses of sound into the water and detects returning pulses of sound.

(a) The transducer emits a pulse of sound and detects an echo from a fish after a time of 37 ms.

speed of sound in water = 1500 m s^{-1}

Calculate the distance between the transducer and the fish.

(3)

$v = f\lambda$ $\frac{37}{2} = \approx 23.5 \text{ m}$

$1500 = \lambda \cdot 23.5$

$\lambda = 63.83 \text{ m}$

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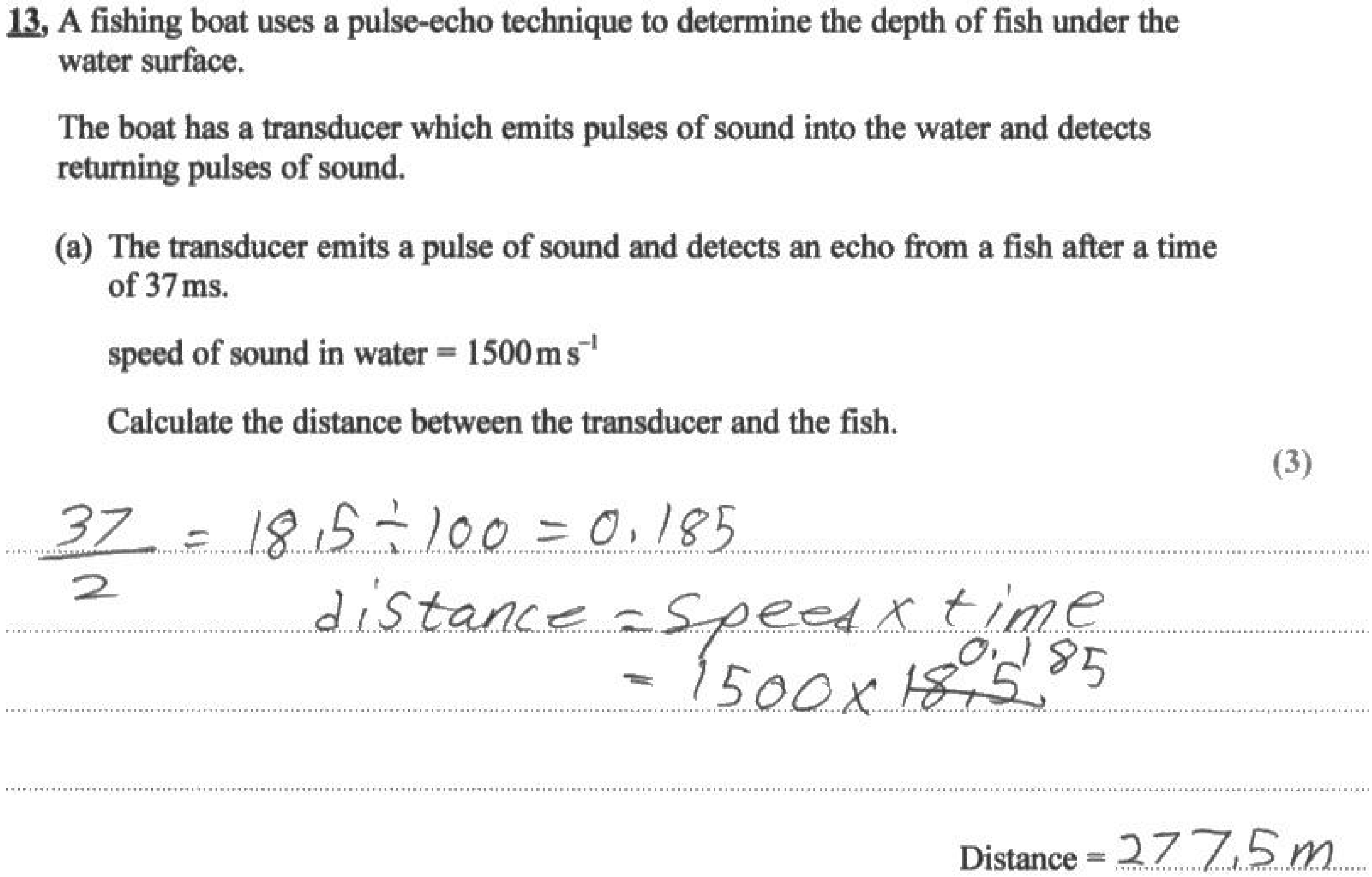
Examiner Comments

This candidate was confused and thought that it was necessary to use the wave equation as a speed of sound had been provided. However, no information was given about the frequency or wavelength of the ultrasound and this equation was of no value. As a consequence no mark was awarded.



13. A fishing boat uses a pulse-echo technique to determine the depth of fish under the water surface.

The boat has a transducer which emits pulses of sound into the water and detects returning pulses of sound.

(a) The transducer emits a pulse of sound and detects an echo from a fish after a time of 37 ms.

speed of sound in water = 1500 m s^{-1}

Calculate the distance between the transducer and the fish.

(3)

$\frac{37}{2} = 18.5 \div 100 = 0.185$

distance = speed x time

$= 1500 \times \overset{0.185}{\cancel{18.5}}$

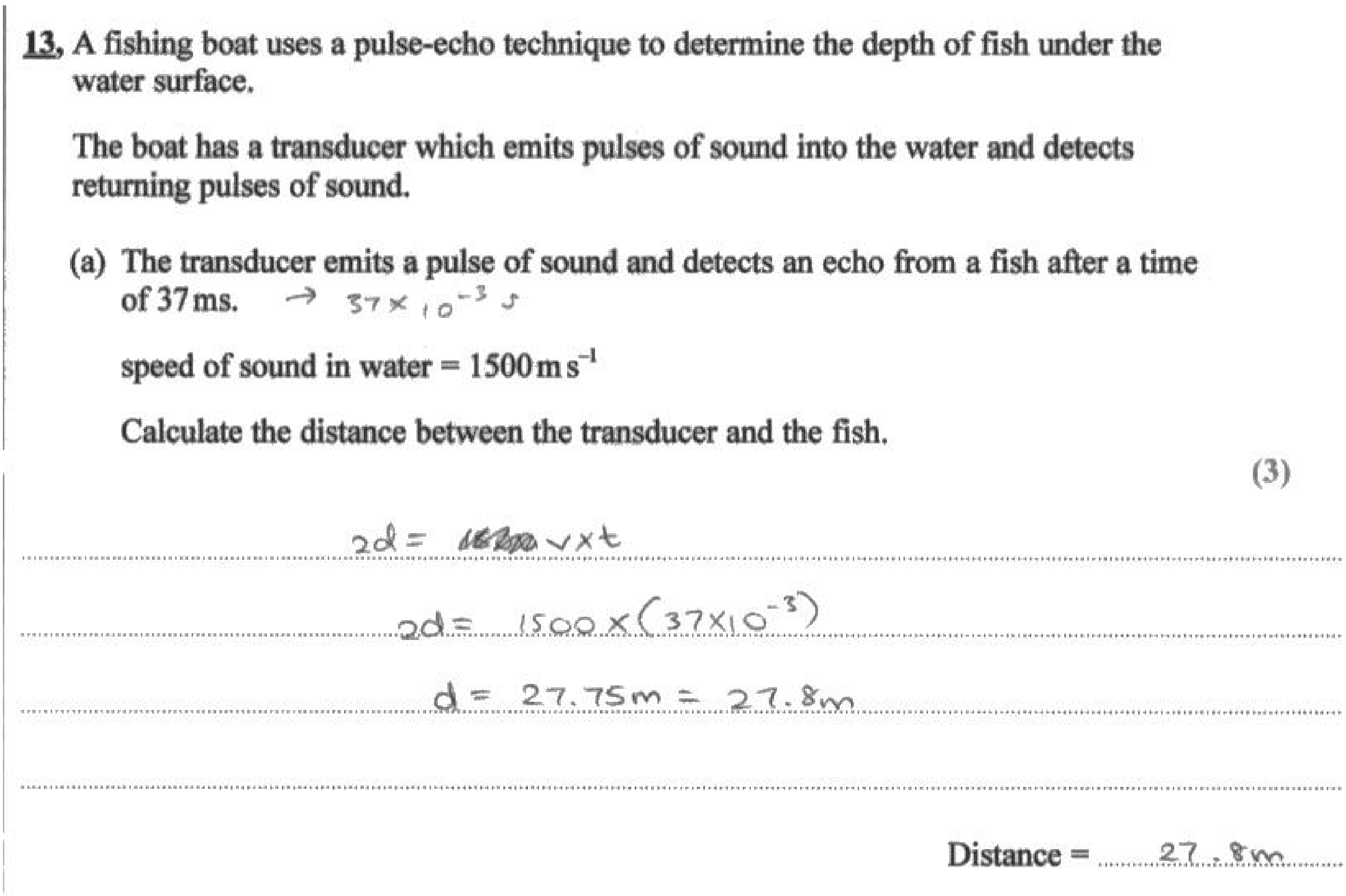
Distance = 277.5 m

ResultsPlus
Examiner Comments

This was a two mark response where the candidate used the correct equation and recognised that the time needed to be halved in order to calculate the correct distance. However, the time had been provided in milliseconds and this candidate failed to convert it correctly. Note that a unit for distance was provided.

ResultsPlus
Examiner Tip

The pulse echo technique does not require a wavelength or frequency to calculate the distance to an object. Always check the magnitude of the quantities provided and convert correctly.



13. A fishing boat uses a pulse-echo technique to determine the depth of fish under the water surface.

The boat has a transducer which emits pulses of sound into the water and detects returning pulses of sound.

(a) The transducer emits a pulse of sound and detects an echo from a fish after a time of 37 ms. → 37×10^{-3} s

speed of sound in water = 1500 m s^{-1}

Calculate the distance between the transducer and the fish.

(3)

$2d = v \times t$

$2d = 1500 \times (37 \times 10^{-3})$

$d = 27.75m = 27.8m$

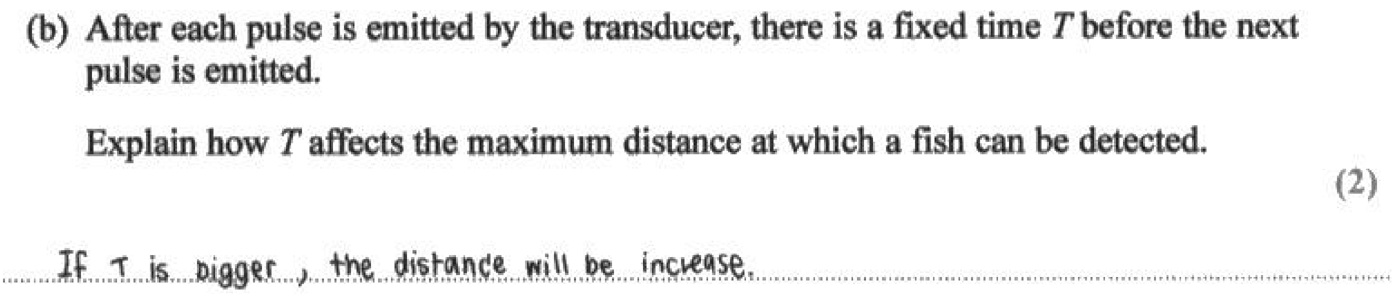
Distance = 27.8m

ResultsPlus
Examiner Comments

A perfect response where the time was double and the correct distance calculated.

Question 13 (b)

This question presented a great deal of difficulty to the majority of candidates and there were many responses that failed to address the question in a logical way. The theme of pulse echo was continuing from the previous part and it should have been obvious that in this technique a pulse is emitted and then detected. If the distance was greater, then the time for a pulse to return would have been longer and as a consequence a second signal would have been emitted before the return of the first. This would have meant that the fish would not have been detected. Therefore the pulse duration limits the distance over which the fish can be located.



(b) After each pulse is emitted by the transducer, there is a fixed time *T* before the next pulse is emitted.

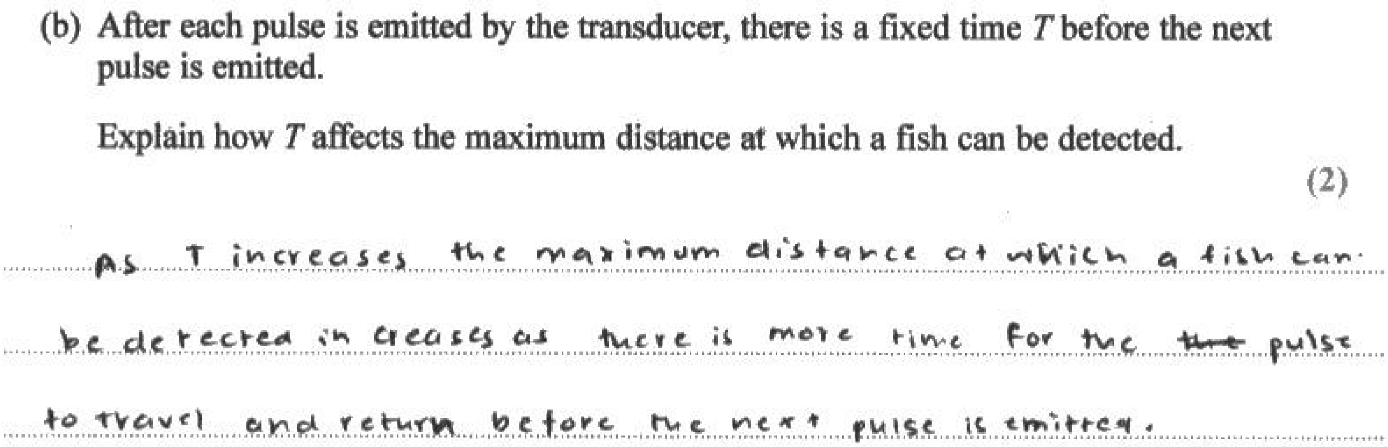
Explain how *T* affects the maximum distance at which a fish can be detected.

(2)

If T is bigger , the distance will be increase.

ResultsPlus
Examiner Comments

This was a simple response but good enough for marking point 1. It linked increasing time with increasing distance but failed to give an explanation as to why this was important.



(b) After each pulse is emitted by the transducer, there is a fixed time *T* before the next pulse is emitted.

Explain how *T* affects the maximum distance at which a fish can be detected.

(2)

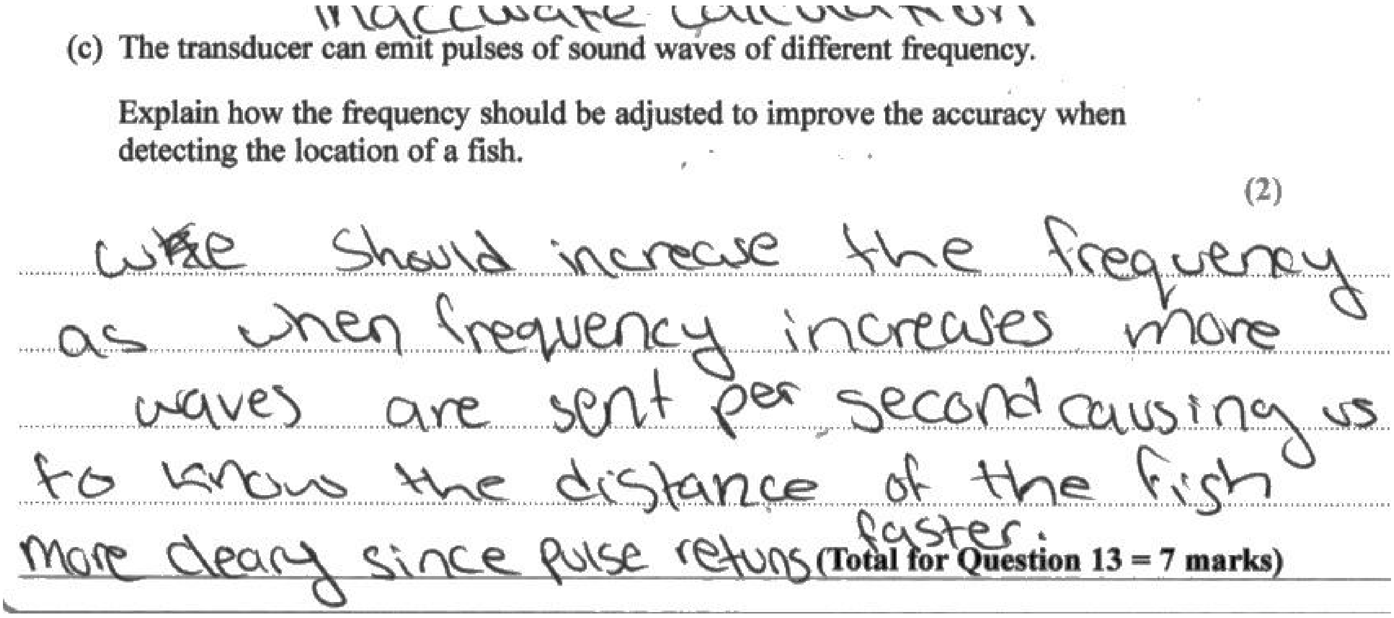
As T increases the maximum distance at which a fish can be detected increases as there is more time for the ~~the~~ pulse to travel and return before the next pulse is emitted.

ResultsPlus
Examiner Comments

This was a very good response where the candidate clearly recognised the importance of timing the transmission of the pulses so that they could cover the distance and return before interfering with another pulse.

Question 13 (c)

This question has appeared in several papers in the past few series albeit in different scenarios. Regardless of the context candidates should be aware that by increasing the frequency of a sound wave, its wavelength must decrease as the speed is constant. As a consequence the shorter wave would diffract less and give a better resolution. In this case it would have enabled the detection of smaller fish.



inaccurate calculation

(c) The transducer can emit pulses of sound waves of different frequency.

Explain how the frequency should be adjusted to improve the accuracy when detecting the location of a fish.

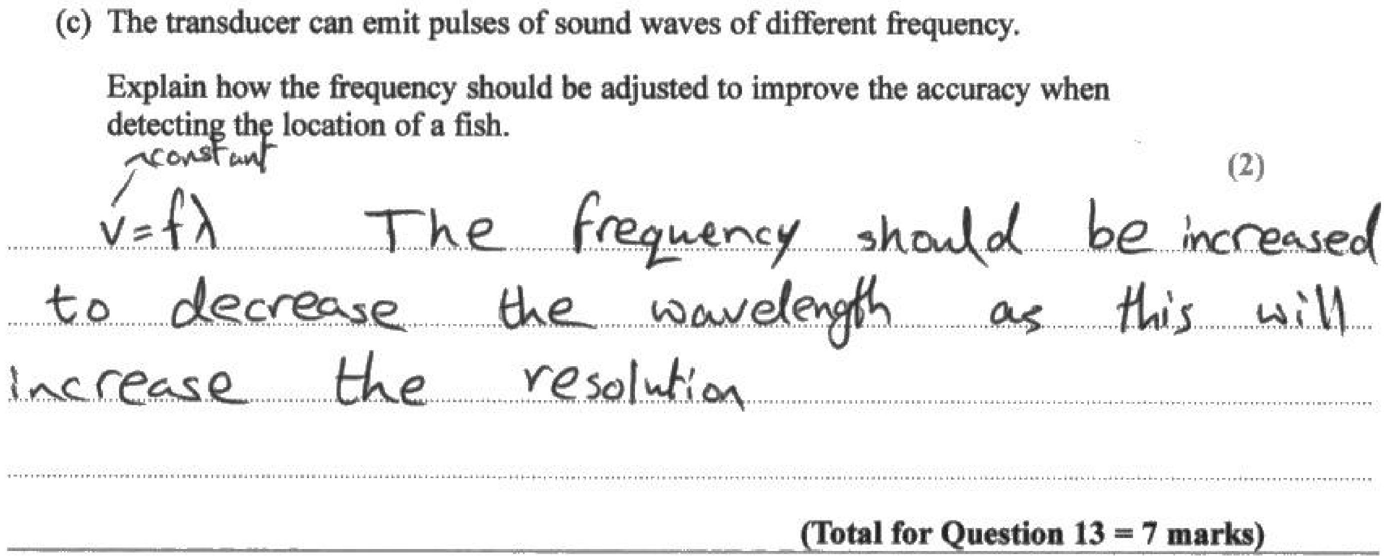
(2)

we should increase the frequency as when frequency increases more waves are sent per second causing us to know the distance of the fish more cleary since pulse retuns faster.

(Total for Question 13 = 7 marks)

ResultsPlus
Examiner Comments

This was a poor response which got off to a promising start by suggesting that the frequency should be increased. Unfortunately this candidate was unaware that the wave would not travel any faster and had no effect on the distance over which the fish could be detected. We wanted an idea of locating a smaller object rather than one that was further away.



(c) The transducer can emit pulses of sound waves of different frequency.

Explain how the frequency should be adjusted to improve the accuracy when detecting the location of a fish.

(2)

$\overset{\text{constant}}{v} = f\lambda$ The frequency should be increased to decrease the wavelength as this will increase the resolution

(Total for Question 13 = 7 marks)

ResultsPlus
Examiner Comments

Although this candidate wrote the wave equation it was not required to receive full credit but it certainly enhanced the response. This was a very good example of a two mark answer.

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Examiner Tip

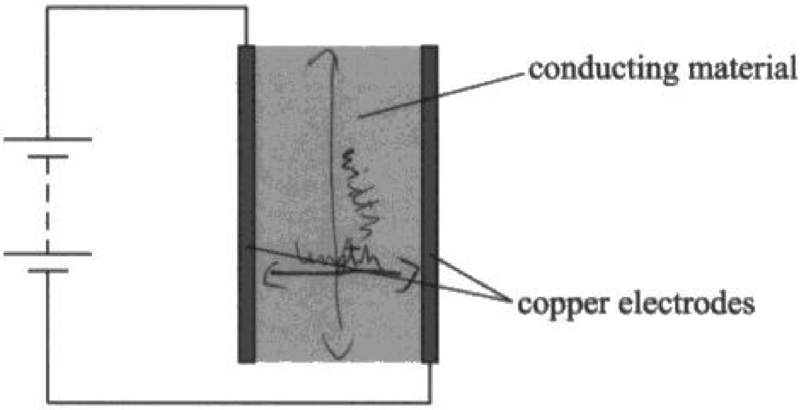
In this context it is important to recognise the relationship between frequency and wavelength and the effect of reducing wavelength on the effectiveness of the pulse echo technique. In this question we were looking for the word resolution or diffraction and gave no credit to responses referring to greater detail or precision.

Question 14 (a)(i)

This question asked for the definition of resistivity and the responses from the vast majority of candidates were poor. Admittedly it is not a question that has been asked often in the past but a sensible candidate should have been aware that a formula linking resistivity and resistance is provided on the question paper and this would have been useful in trying to answer this question.

14) An electrical heating system consists of heating panels.

Each panel is made from a thin sheet of conducting material attached to two copper electrodes. The electrodes are connected to a power supply, as shown.



(a) A student uses a sample of the conducting material to determine its resistivity.

(i) State what is meant by resistivity of a material.

(1)

Resistivity is $\frac{RA}{l} = \rho$ it is a physical quantity that is different for every metal.

ResultsPlus
Examiner Comments

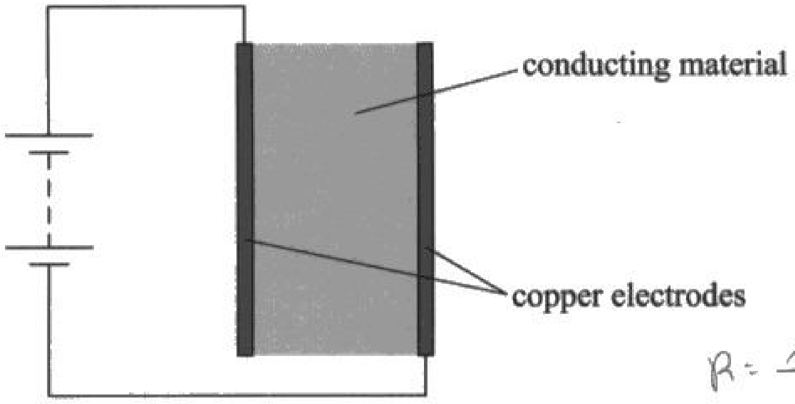
Interestingly this candidate wrote down a correct formula but did not do anything with it. Had they defined the terms in the equation then the mark would have been awarded.

ResultsPlus
Examiner Tip

If you are unclear of a definition then often a formula can help you.

14, An electrical heating system consists of heating panels.

Each panel is made from a thin sheet of conducting material attached to two copper electrodes. The electrodes are connected to a power supply, as shown.



$R = \frac{\rho L}{A}$

$\frac{RA}{L}$

(a) A student uses a sample of the conducting material to determine its resistivity.

(i) State what is meant by resistivity of a material.

(1)

It is the resistance × crossectional area per unit length. $\rho = \frac{RA}{L}$

it's a property of a material.

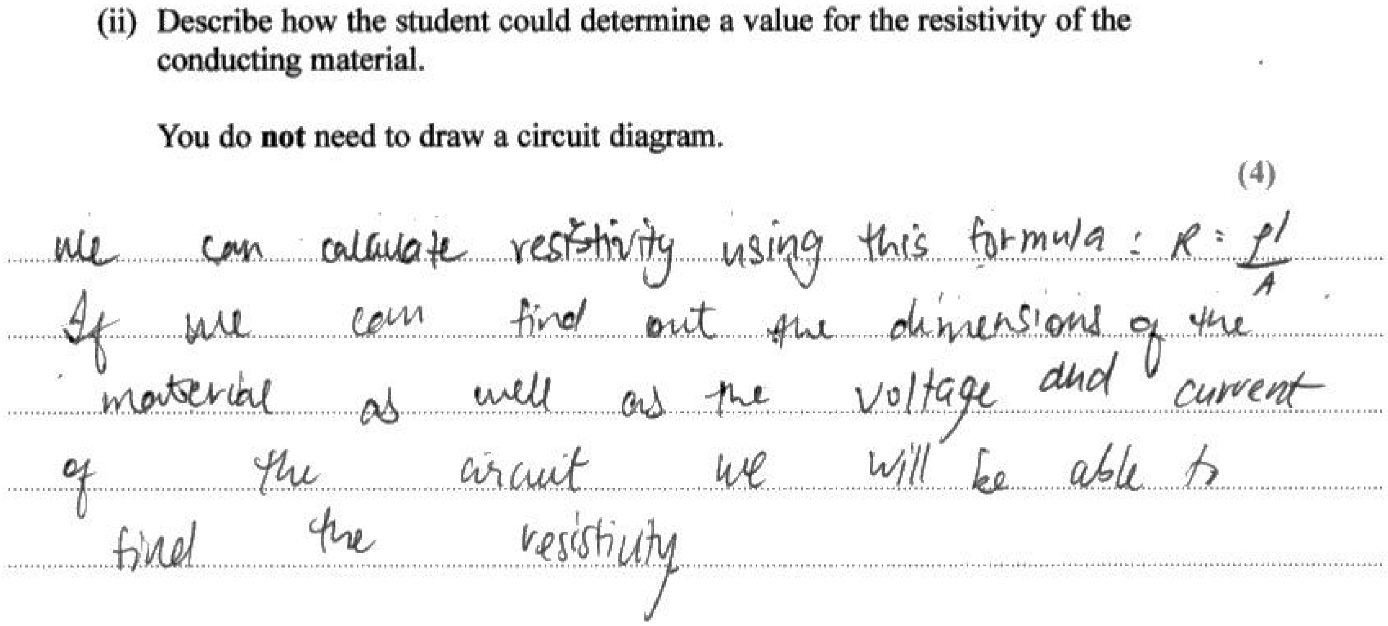
ResultsPlus

Examiner Comments

A very good response where it is worth noting that the definition required the idea of cross-sectional area rather than just area and unit length rather than just length.

Question 14 (a)(ii)

In this part of the question a diagram of a conducting material in a circuit was provided and candidates were asked to describe how a value for resistivity could be determined for the material. This context was related to a required practical which candidates can expect to be asked about in this paper. Once again a good starting point to help with a structured answer would have been to make use of the formula linking resistance with resistivity. Using R = ρl/A to determine a value for resistivity we then need to know how to find the other values in the equation. The width, length and thickness all need to be measured as well as a method for calculating R. This could have been done using an ammeter and voltmeter to record current and potential difference that then could have been substituted into Ohm's law. With these values known a calculated area and resistance, along with a measure length could have been substituted into the rearranged formula ρ = RA/L.



(ii) Describe how the student could determine a value for the resistivity of the conducting material.

You do **not** need to draw a circuit diagram.

(4)

we can calculate resistivity using this formula : $R = \frac{\rho l}{A}$ If we can find out the dimensions of the material as well as the voltage and current of the circuit we will be able to find the resistivity

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Examiner Comments

This candidate made no attempt to describe how the student could measure the required values and was awarded no marks for this response.

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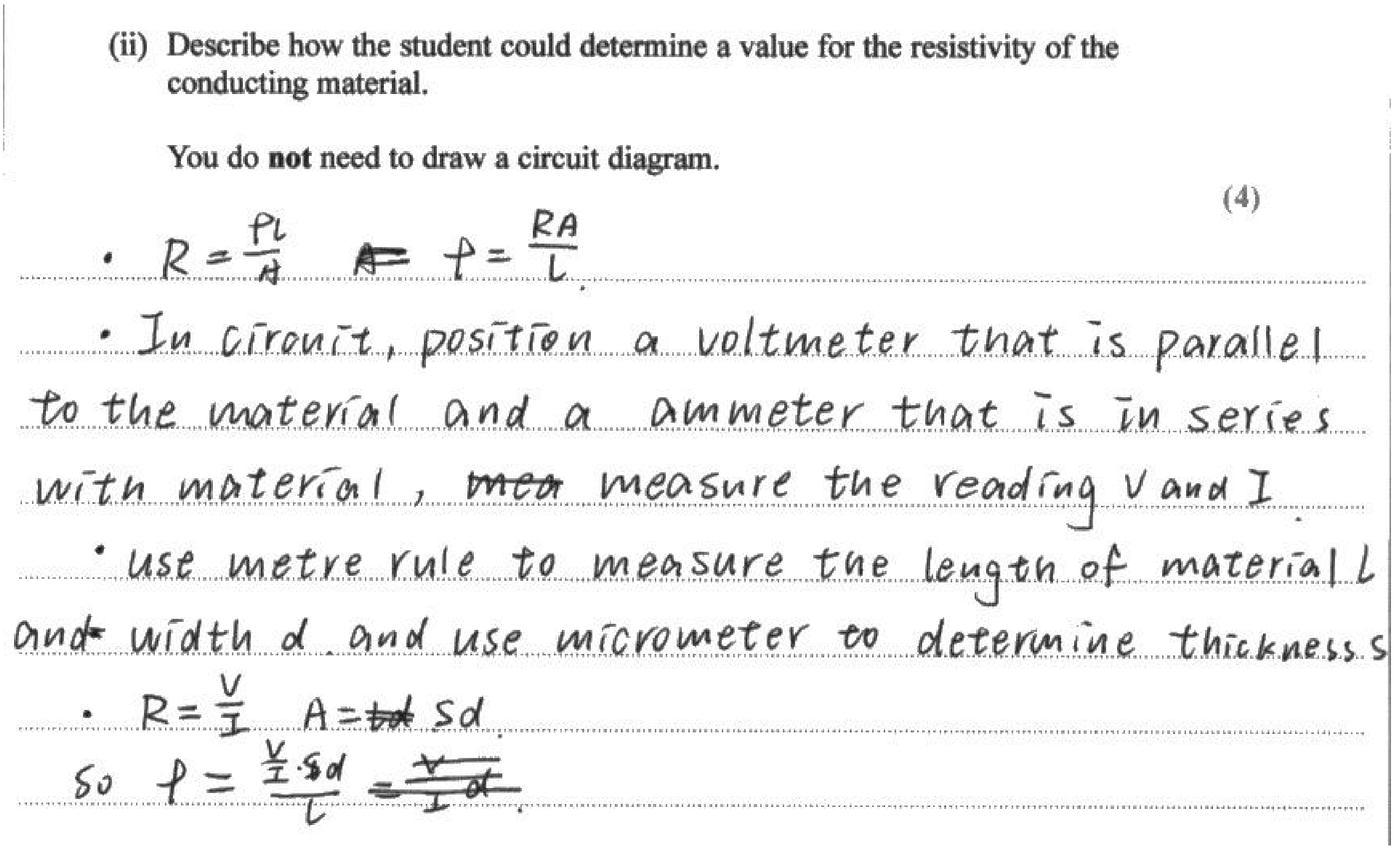
Examiner Tip

The word describe in a question requires an account of something. Statements in the response need to be developed as they are often linked.



(ii) Describe how the student could determine a value for the resistivity of the conducting material.

You do **not** need to draw a circuit diagram.

(4)

- $R = \frac{\rho L}{A}$ ~~A=~~ $\rho = \frac{RA}{L}$.
- In circuit, position a voltmeter that is parallel to the material and a ammeter that is in series with material, ~~mea~~ measure the reading V and I.
- use metre rule to measure the length of material L and width d and use micrometer to determine thickness s
- $R = \frac{V}{I}$ A = ~~td~~ sd.

so $\rho = \frac{\frac{V}{I} \cdot sd}{L}$ ~~$= \frac{V}{I} \cdot d$~~.

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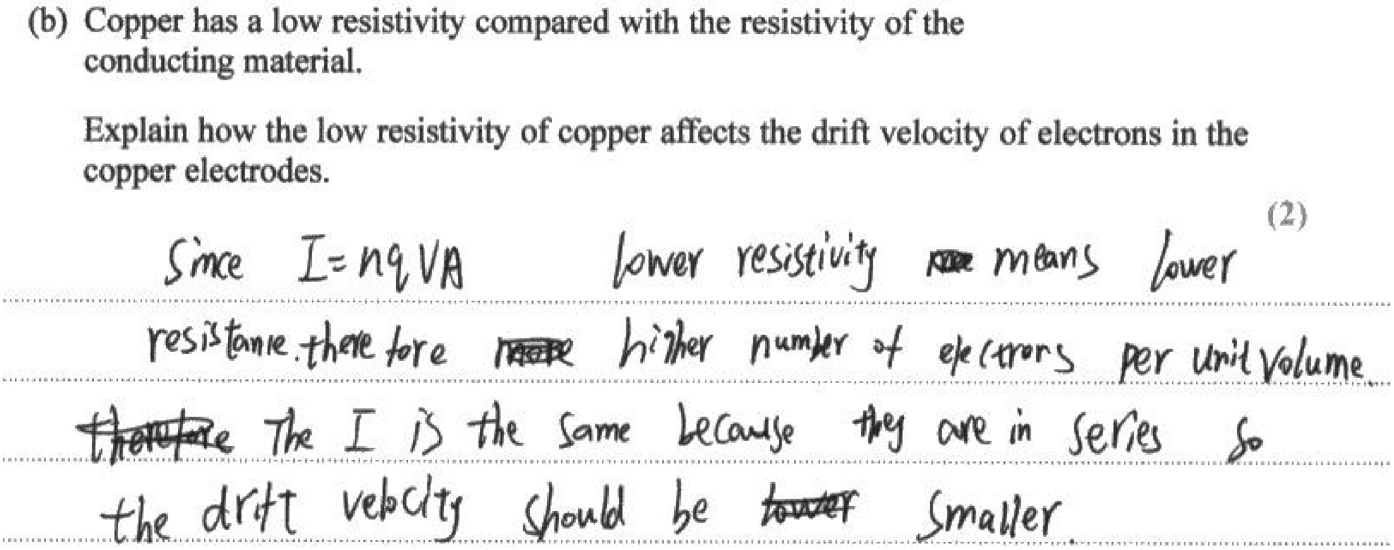
Examiner Comments

This is a concise but detailed response which covers all four of the marking points. This candidate has clearly carried out such an experiment and has demonstrated obvious practical skills. The answer follows logical steps and these instructions could be followed easily.

Question 14 (b)

This question proved to be quite a challenge to the vast majority of candidates as very few achieved either of the first or second marking points. The key word in the question was resistivity and therefore it would have been prudent to refer back to R = ρl/A and rearrange for resistivity. This should have enabled candidates to establish that R must have been lower and as a consequence there would be more charge carriers in copper thus lower drift velocity in copper due to v = I/nAq being smaller.



(b) Copper has a low resistivity compared with the resistivity of the conducting material.

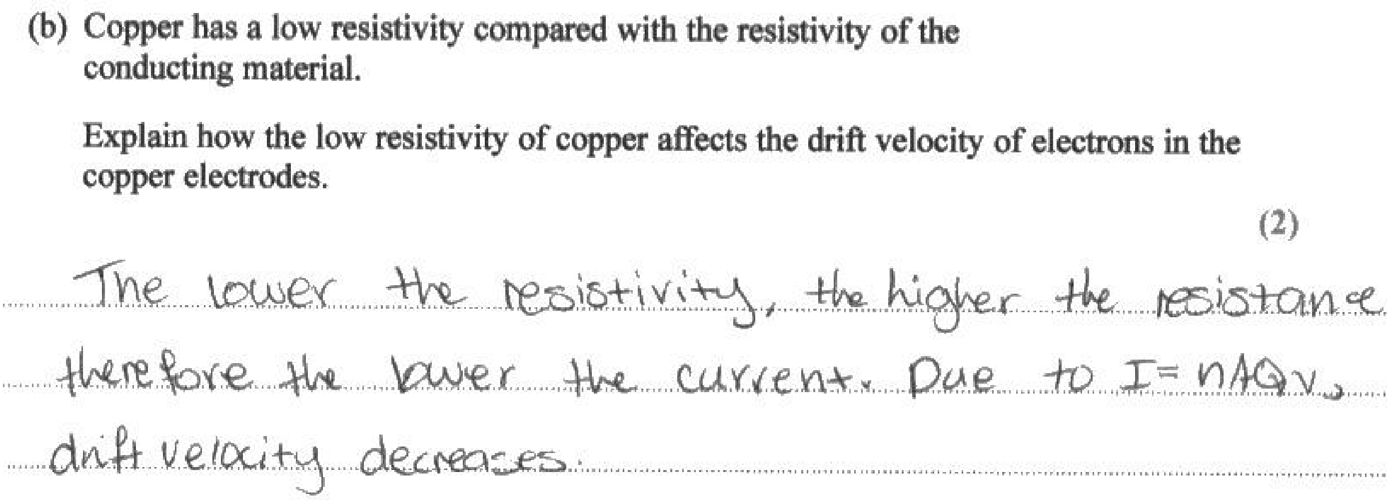
Explain how the low resistivity of copper affects the drift velocity of electrons in the copper electrodes.

(2)

Since $I = nqVA$ lower resistivity means lower resistance. therefore higher number of electrons per unit volume ~~therefore~~ The I is the same because they are in series so the drift velocity should be ~~lower~~ smaller.

ResultsPlus
Examiner Comments

This was a very good answer where the lower resistance was clearly linked to the increase in charge carriers and lower drift velocity.



(b) Copper has a low resistivity compared with the resistivity of the conducting material.

Explain how the low resistivity of copper affects the drift velocity of electrons in the copper electrodes.

(2)

The lower the resistivity, the higher the resistance therefore the lower the current. Due to $I = nAQv$, drift velocity decreases.

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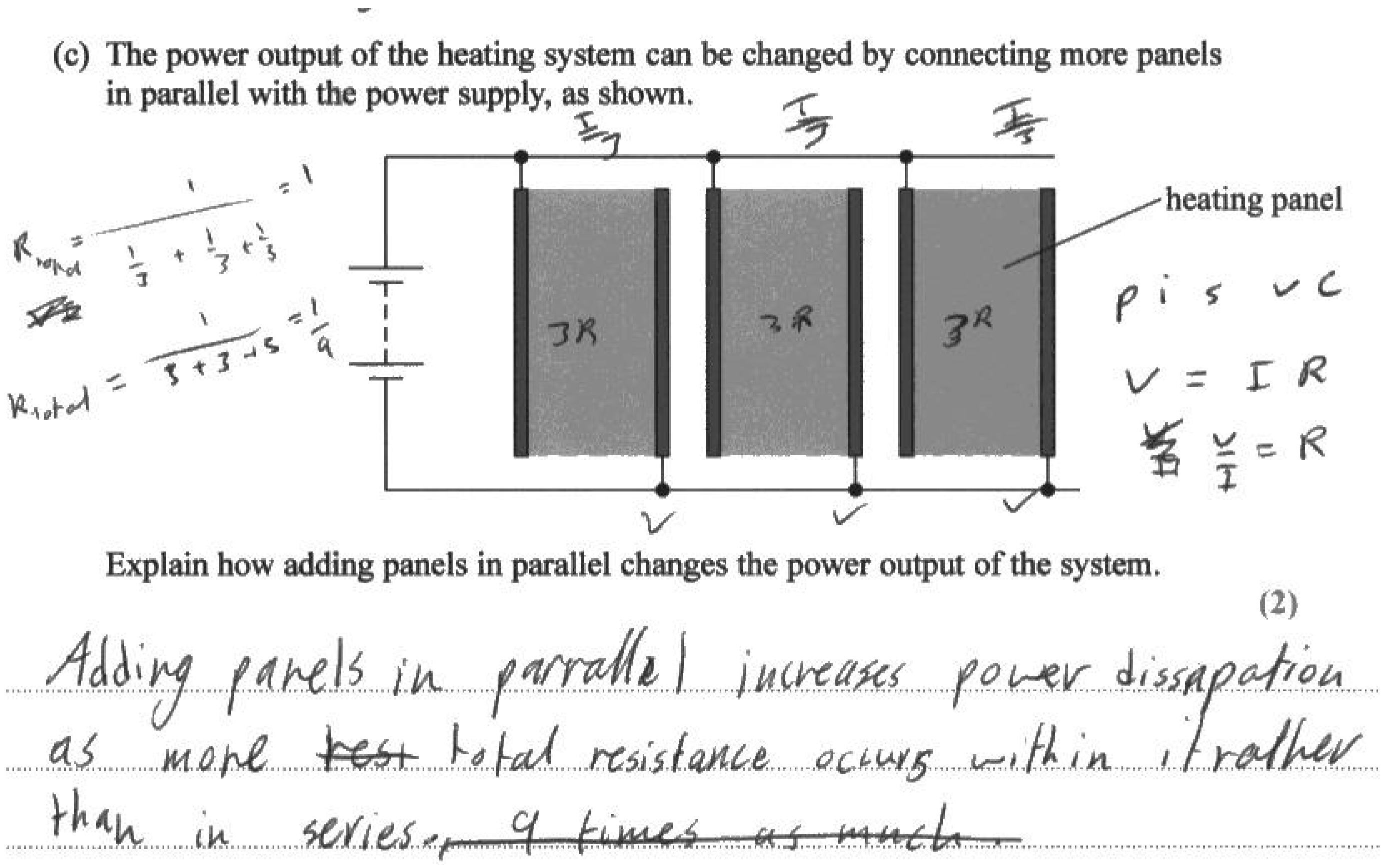
Examiner Comments

This candidate was unsure about the relationship between the number of charge carriers and drift velocity but was awarded marking point 2 for the statement linked to the relevant formula.

Question 14 (c)



(c) The power output of the heating system can be changed by connecting more panels in parallel with the power supply, as shown.

Explain how adding panels in parallel changes the power output of the system.

(2)

Adding panels in parrallel increases power dissapation as more ~~rest~~ total resistance occurs within it rather than in series, ~~9 times as much.~~

ResultsPlus
Examiner Comments

This candidate recognised that there were more resistors being placed in parallel and recognised that this would result in more power. However, there was no link to any of the power equations and the response became confused.

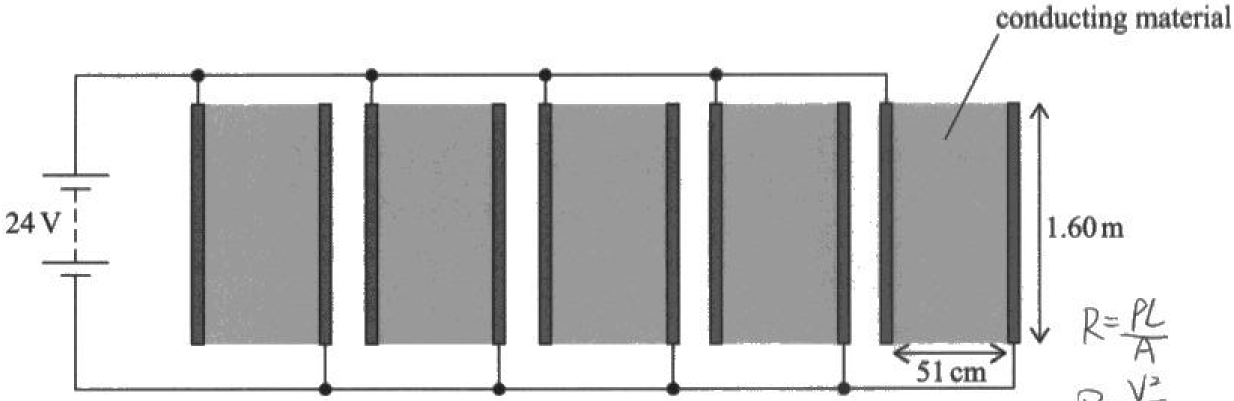
ResultsPlus
Examiner Tip

Remember to refer to power equations in circuits as these will provide the relationship between current, p.d. and power.

Question 14 (d)

In this scenario candidates were presented a problem in which a deduction of whether a heating system could be operated safely had to be made. The solution involved using the equation R = ρl/A but there was an unusual arrangement of the conducting materials in that the length to be used was the shorter side and the depth had to be multiplied by the length of the longer side to calculate the cross sectional area. Unfortunately, the majority of candidates failed to recognise this and were limited to a maximum of three marks from the five available.

(d) A student designs a heating system using five heating panels, as shown.



$R = \frac{\rho L}{A}$

$P = \frac{V^2}{R}$

To be safe, the maximum power of the student's heating system should be less than 350 W.

$\rho = \frac{m}{V}$

Deduce whether the student's heating system is safe.

resistivity of conducting material = $6.4 \times 10^{-3}\,\Omega\,\text{m}$
thickness of conducting material = 0.48 mm

(5)

~~5×~~

~~$\frac{1}{6.4\times10^{-3}}$ ×5 = $1.28\times10^{-3}\,\Omega\text{m}$~~

$P = \frac{V^2}{R}$

$= \frac{24^2}{6.4\times10^{-3}} = 90000\text{ W}$

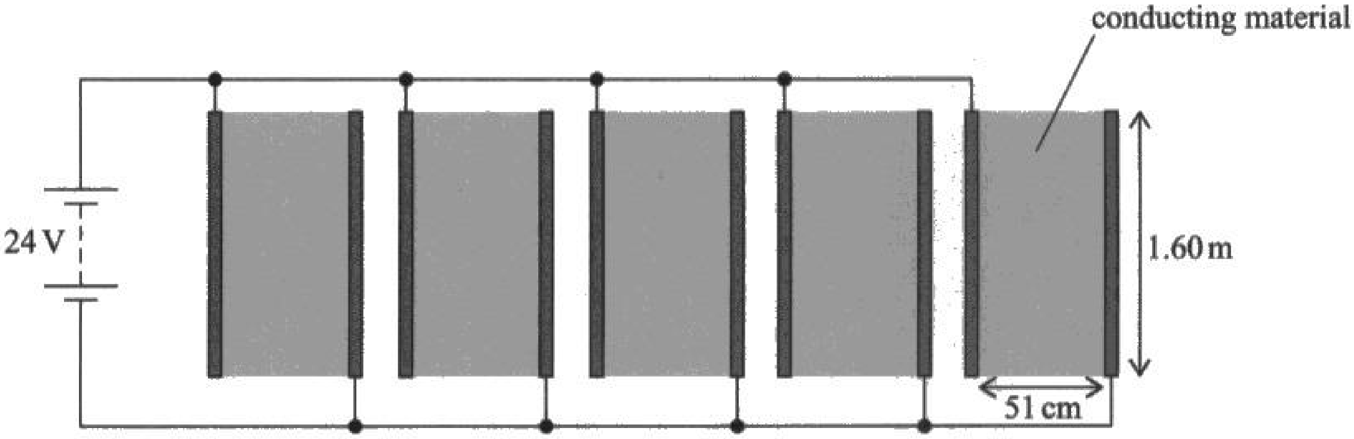
$90000\text{W} > 350\text{W}$

∴ No

ResultsPlus
Examiner Comments

This candidate had written the relevant formula on the top right of the answer space but made no further progress with it. It would have been possible for this response to score the fourth marking point for the use of a power equation. However, as can be seen, the value for resistivity was incorrectly substituted into the equation.

(d) A student designs a heating system using five heating panels, as shown.



To be safe, the maximum power of the student's heating system should be less than 350 W.

Deduce whether the student's heating system is safe.

resistivity of conducting material = $6.4 \times 10^{-3}\,\Omega\,\text{m}$
thickness of conducting material = 0.48 mm

(5)

$R = \frac{\rho L}{A}$. $A = 1.6 \times 0.51 = 0.816\,\text{m}^2$ $R = \frac{6.4 \times 10^{-3} \times 0.48 \times 10^{-2}}{0.816} = 3.76 \times 10^{-5}\,\Omega$

$\frac{1}{R_{total}} = \frac{1}{3.76 \times 10^{-5}} \times 5 = 1.33 \times 10^{5}\,\Omega$.

$R_{total} = \frac{1}{1.33 \times 10^{5}} = 7.52 \times 10^{-6}\,\Omega$.

$P = \frac{V^2}{R} = \frac{24^2}{7.56 \times 10^{-6}} = 7.62 \times 10^{7}\,\text{W}$

ResultsPlus
Examiner Comments

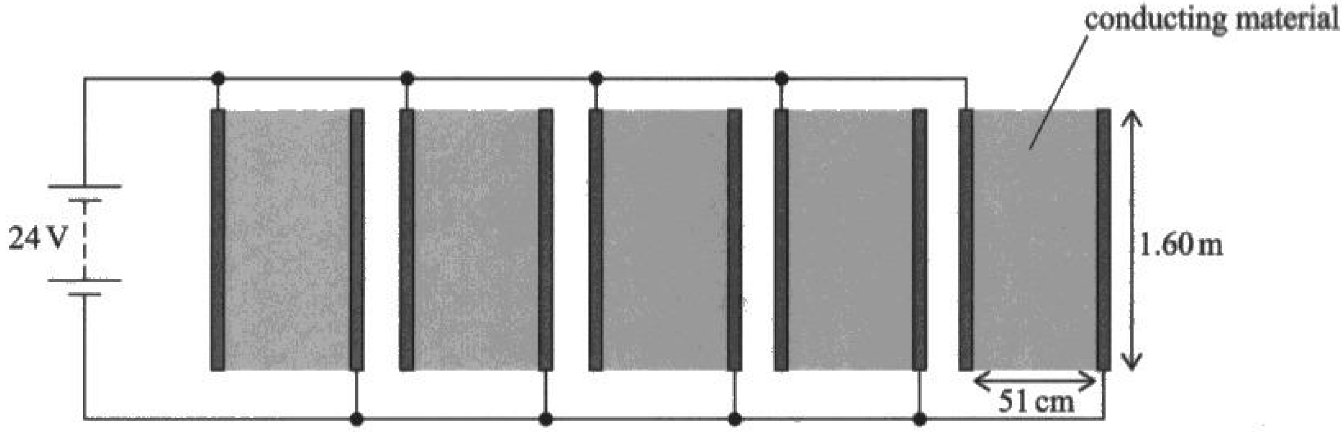
This candidate made the common error of selecting the wrong value to calculate the width and was not awarded the first marking point. The second making point was awarded for a correct use of the resistivity formula. The fourth marking point was not awarded as the correct arrangement of the resistance of the 5 panels was not made. However, although an incorrect resistance value was calculated it was correctly used in a power equation and so the fourth marking point was awarded.

ResultsPlus

Examiner Tip

Marks can be awarded for the correct use of formulae with incorrectly calculated values as long as they are dimensionally correct. It is always worth trying to complete a calculation even though you may be aware that some of your values are wrong.

(d) A student designs a heating system using five heating panels, as shown.



To be safe, the maximum power of the student's heating system should be less than 350 W.

Deduce whether the student's heating system is safe.

resistivity of conducting material = $6.4 \times 10^{-3}\,\Omega\text{m}$
thickness of conducting material = 0.48 mm

(5)

$R = \frac{\rho L}{A} = \frac{6.4 \times 10^{-3}\,\Omega\text{m} \times 0.51\,\text{m}}{1.6\,\text{m} \times 0.48 \times 10^{-3}\,\text{m}} = 4.25\,\Omega$

$\therefore R_{total} = \frac{1}{5} \cdot R = \frac{1}{5} \times 4.25\,\Omega = 0.85\,\Omega$

$\therefore$ ~~B~~ $P = \frac{V^2}{R} = \frac{(24V)^2}{0.85\,\Omega} = 678\,\text{W}$

which higher than 350W
$\therefore$ it is not safe.

ResultsPlus
Examiner Comments

This was a concisely executed calculation that gained all the marks. The area was correctly calculated within the resistivity formula and a correct value for length was substituted. The resistance value calculated was used to calculate the total resistance for the 5 panels and this correctly calculated value was used in a power equation. The correct value for power was calculated and a correct deduction was made.

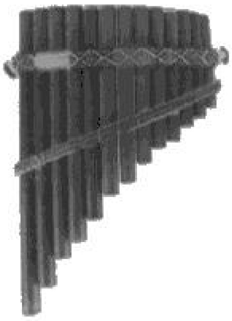
ResultsPlus
Examiner Tip

In a deduction question make sure to compare the calculated value with the given value and make a valid statement otherwise the final mark will not be awarded.

Question 15 (a)

In this question candidates were required to determine the time period of a wave from an oscilloscope trace and use this to calculate the frequency of the wave. This style of question is not uncommon and should have presented little difficulty for the majority of candidates. However, the majority of responses used a time period calculated from a single wavelength when the first marking point required a minimum of three waves to be used. Some candidates also confused the large divisions with the smaller divisions on the scale. The consequences of these errors resulted in a frequency value outside of the acceptable range and this limited many responses to a maximum of one mark.

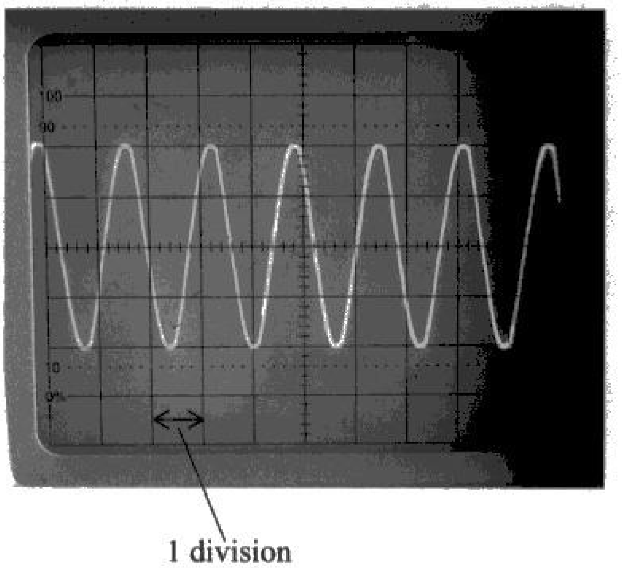
15) The photograph shows a musical instrument called panpipes.



(Source: © barisonal/Getty Images)

The instrument is made using pipes of different lengths. Blowing air across the top of one of the pipes produces a sound.

(a) A student connected a microphone to an oscilloscope. She then placed the microphone near to one of the pipes. The photograph below shows the oscilloscope screen when the pipe was producing a sound.



Calculate an accurate value for the frequency of the sound wave.

1 division = 1.5 ms

(3)

$s = f \times \lambda$

$1.5 = f \times 3$

0.5 Hz $= F$

Frequency = 0.5 Hz

ResultsPlus
Examiner Comments

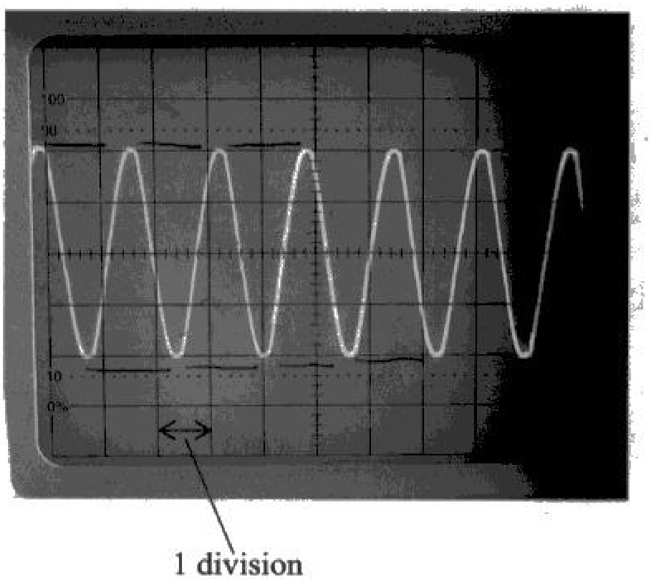
This candidate simply took the time period for one division and substituted this into the wave equation. Had they calculated 1/1.5ms they would have scored the second marking point. The wave equation is of no value here as the frequency could be calculated from 1/T. No marks were scored in this response.

15. The photograph shows a musical instrument called panpipes.

(Source: © barisonal/Getty Images)

The instrument is made using pipes of different lengths. Blowing air across the top of one of the pipes produces a sound.

(a) A student connected a microphone to an oscilloscope. She then placed the microphone near to one of the pipes. The photograph below shows the oscilloscope screen when the pipe was producing a sound.



1 division

Calculate an accurate value for the frequency of the sound wave.

1 division = 1.5 ms

(3)

5 division = 1.5ms × 5 = 7.5×10^{-3} s

7.5×10^{-3} s ÷ 3 = 2.5×10^{-3} s

$f = \frac{1}{T} = \frac{1}{2.5 \times 10^{-3}\,s} = 400\,Hz$

Frequency = 400 Hz

ResultsPlus
Examiner Comments

This candidate correctly used three waves to work out the time period for the first marking point. The reciprocal of the time period led to a value for frequency within the acceptable range and a unit was provided.

ResultsPlus
Examiner Tip

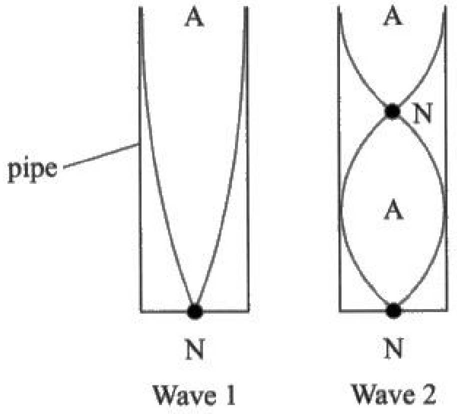
When taking values from an oscilloscope trace use as wide a range of waves as possible as this will be more likely to lead to a calculated value within the range.

Question 15 (b)

Waves formed in an open ended tube which is closed at the other end have appeared in many previous papers. It should be common knowledge by now that the wavelength of the simplest wave in such a tube is four times the length and so for wave one λ = 4L would have given the wavelength. Wave two was slightly more difficult to work out but it should have been clear that 3/4 of a wave in the tube and that its wavelength was therefore 4/3L for the first marking point. A comparison could then have been made between the wavelength of the two waves. It should have been clear at this stage that the velocity of the two waves was constant so by using the wave equation v = f λ the correct relationship between the frequency of these two waves could have been deduced.

(b) Each pipe is open at the top and closed at the bottom. When air is blown across the open end, a stationary wave is formed in the pipe.

The student was able to produce two sounds from the same pipe. The diagram shows the nodes N and antinodes A in the stationary waves that caused each sound.



Explain how the frequency of wave 1 compares with the frequency of wave 2.

(3)

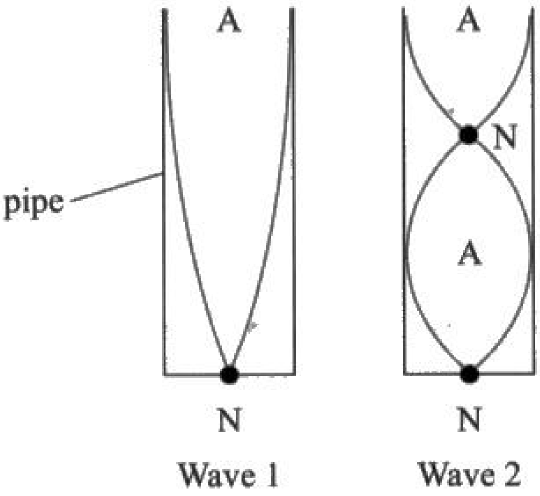
$v=f\lambda$, $f=\frac{v}{\lambda}$. The wavelength of wave 1 is greater than that of wave2 as the length from node to antinode is greater.
So the frequency of wave 1 is smaller than that of wave 2. $f=\frac{v}{\lambda}$

ResultsPlus
Examiner Comments

This was an all too common response where very basic comparisons between the wavelength or frequency of the waves were made. However, the question asks for an explanation and as such these simple comparisons will never be worthy of credit.

(b) Each pipe is open at the top and closed at the bottom. When air is blown across the open end, a stationary wave is formed in the pipe.

The student was able to produce two sounds from the same pipe. The diagram shows the nodes N and antinodes A in the stationary waves that caused each sound.



$L = \frac{3}{4}\lambda$

Explain how the frequency of wave 1 compares with the frequency of wave 2.

(3)

Set the length of the pipe is L $v = f\lambda$

wavelenght of wave 1 = 4L

frequency of wave 1 = $\frac{v}{4L}$

wavelength of wave 2 = $\frac{4}{3}L$

frequency of wave 2 = $v \times \frac{3}{4L} = \frac{3}{4} \cdot \frac{v}{L} = 3 \cdot \frac{v}{4L}$

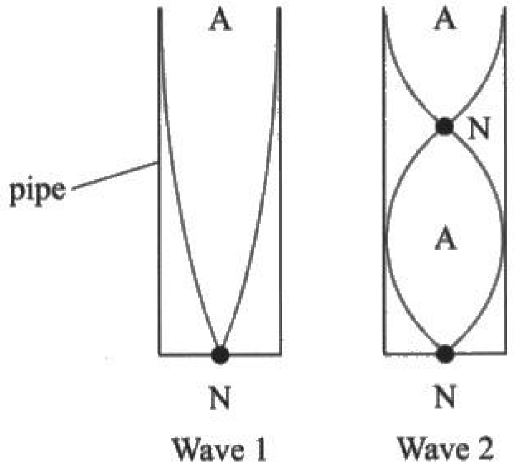
$f_2 = 3f.$

ResultsPlus
Examiner Comments

This was a well presented response that scored the first and third marking points. The wavelength for each wave was correctly calculated and a rearrangement led to the correct comparison of the frequency of the two waves. What was missing here was an explanation that this relationship could be worked out from the wave equation as the speed of sound was the same for each wave.

(b) Each pipe is open at the top and closed at the bottom. When air is blown across the open end, a stationary wave is formed in the pipe.

The student was able to produce two sounds from the same pipe. The diagram shows the nodes N and antinodes A in the stationary waves that caused each sound.



Explain how the frequency of wave 1 compares with the frequency of wave 2.

(3)

- The wavelength of wave 1 is 3 times that of wave 2
- as velocity is the same, from $v=f\lambda$, frequency of wave 1 is a third of frequency of wave 2.

ResultsPlus
Examiner Comments

This was a concise and well worded three mark response from a candidate who had clearly taken the time to analyse each of the two diagrams and arrive at the correct response.

Question 15 (c)

In this question a graph of wavelength against 1/frequency was provided which contained 5 plotted points. Candidates were asked to determine a value for the velocity of the wave and it should have been straightforward to deduce that the gradient of such a graph would provide the answer. The first mark here required a line of best fit to be drawn and a gradient taken. The second mark was for a value of velocity within the acceptable range.

(c) The student determined the frequency and wavelength of sound waves produced in different pipes and plotted the graph shown.

(0.0015, 0.485)

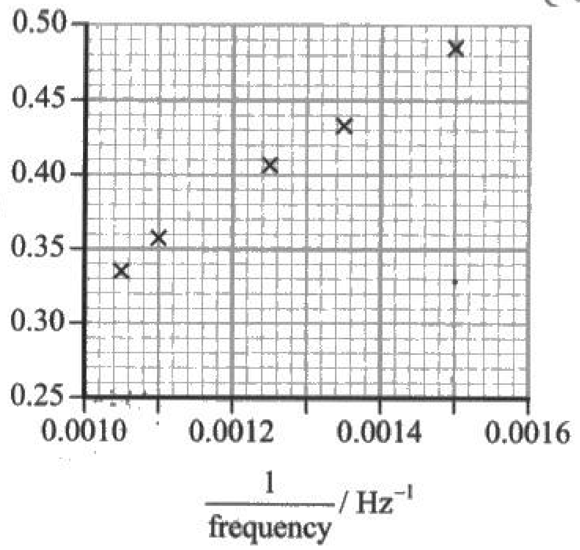
(~~0.485, 0.0015~~)

(

0.00105

~~0.0015~~

(~~0.0015~~, 0-335)



Determine a value for the speed of sound.

(2)

$v = f\lambda$

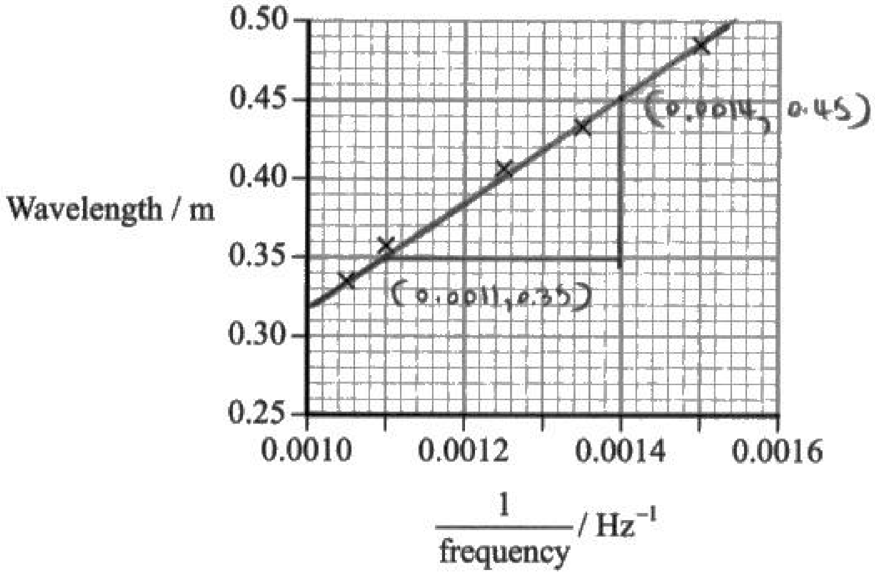
$m = \frac{0.0015 - 0.00105}{0.485 - 0.335} = 3 \times 10^{-3}\ ms^{-1}$

Speed of sound = $3 \times 10^{-3}\ ms^{-1}$

ResultsPlus
Examiner Comments

In this response there was no attempt to draw a line of best fit but there was an attempt at a gradient calculation, albeit that this candidate had calculated dx/dy and so scored 0 marks.

(c) The student determined the frequency and wavelength of sound waves produced in different pipes and plotted the graph shown.



Determine a value for the speed of sound.

(2)

$V = f\lambda$

$M = \frac{y_2 - y_1}{x_2 - x_1} = \frac{0.45 - 0.35}{0.0014 - 0.0011}$

Gradient $= \lambda \div \frac{1}{f}$

$= \lambda \times f$

$= 333.3 ms^{-1}$

$V =$ gradient $= 333 ms^{-1}$

Speed of sound = 333 ms^{-1}

ResultsPlus
Examiner Comments

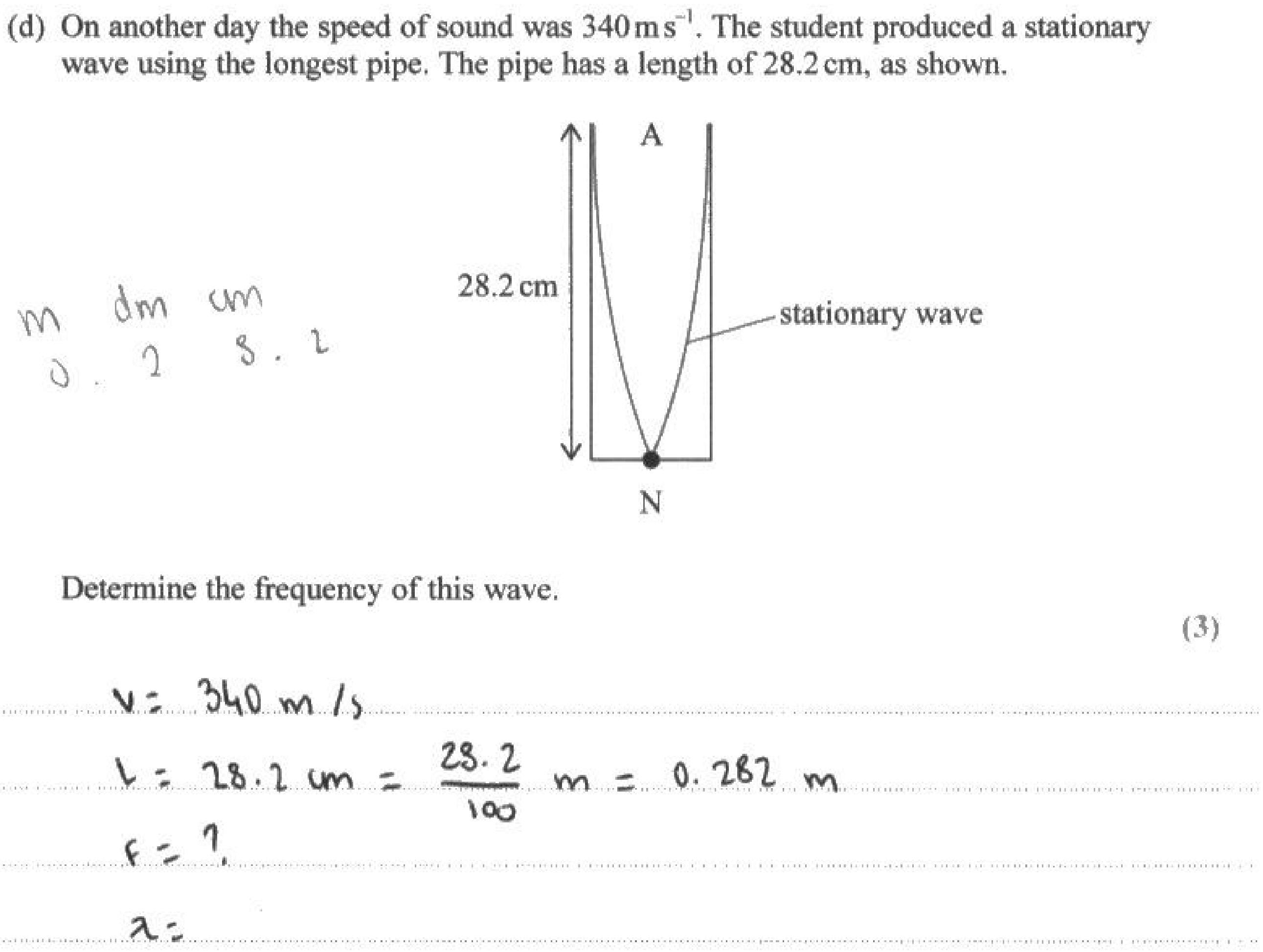
A good two mark response where a very accurate line of best fit was drawn and a gradient calculation completed leading to a velocity value within the acceptable range.

ResultsPlus
Examiner Tip

When a graph is provided that has plotted points with no line drawn it is usually an expectation that a line would be drawn by the candidate.

Question 15 (d)

In this part, candidates have been provided with a diagram similar to wave one in part (b) but this time the length of the tube has been provided along with the speed of sound in air. The frequency needed to be calculated using the wave equation. Candidates who were successful in part (b) would most likely have scored three marks here as they would have recognised that the wavelength of this wave was 4 times the length given or 1.13m. This could then have been used in the wave equation to calculate the speed to be 333 ms^{-1}. Unfortunately the majority of candidates could not work out the correct wavelength and were limited to a maximum of one mark for the use of the wave equation.



(d) On another day the speed of sound was 340 $m s^{-1}$. The student produced a stationary wave using the longest pipe. The pipe has a length of 28.2 cm, as shown.

m dm cm
0 . 2 8 . 2

Determine the frequency of this wave.

(3)

$v = 340 \text{ m/s}$

$l = 28.2 \text{ cm} = \frac{28.2}{100} \text{ m} = 0.282 \text{ m}$

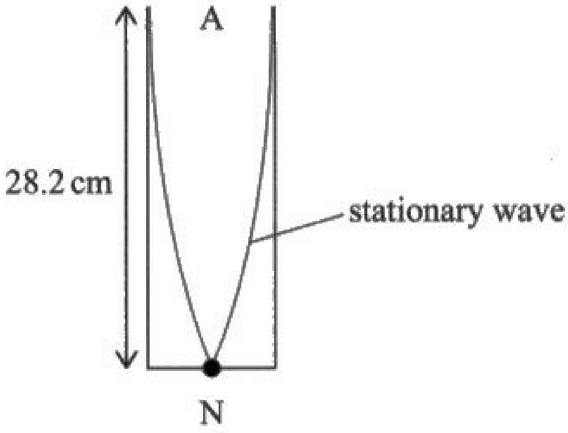
$f = ?$

$\lambda =$

ResultsPlus
Examiner Comments

This candidate correctly converted the length to metres but was unclear as to how to proceed and was unable to use the diagram to establish a value for wavelength. Had they just used 0.282m in the wave equation they would have scored the first marking point.

(d) On another day the speed of sound was 340 m s^{-1}. The student produced a stationary wave using the longest pipe. The pipe has a length of 28.2 cm, as shown.



Determine the frequency of this wave.

(3)

$v = f\lambda$

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

$f = \frac{340}{\frac{28.2}{100} \times 2}$

$f = 602.8 Hz$

$f = 603 Hz$

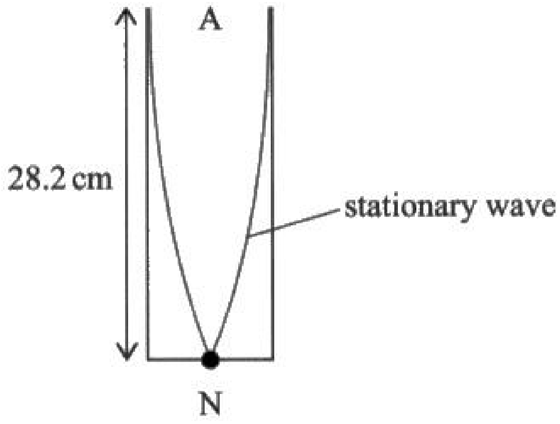
Frequency = 603 Hz

(Total for Question 15 = 11 marks)

ResultsPlus
Examiner Comments

This was a very common answer where the wavelength was calculated to be 2 times the length of the tube but as the wave equation was used correctly the first marking point was awarded.

(d) On another day the speed of sound was 340 m s^{-1}. The student produced a stationary wave using the longest pipe. The pipe has a length of 28.2 cm, as shown.



Determine the frequency of this wave.

(3)

According to the diagram:

$\lambda = 4 \times 28.2 \times 10^{-2} = 1.128\,m$

$v = \lambda f \Rightarrow f = \frac{v}{\lambda} = \frac{340}{1.128} = 301\,Hz$

Frequency = 301 Hz

ResultsPlus
Examiner Comments

This was a perfect three mark response where the correct wavelength was calculated and used correctly in the wave equation to arrive at the correct value with the required unit.

ResultsPlus
Examiner Tip

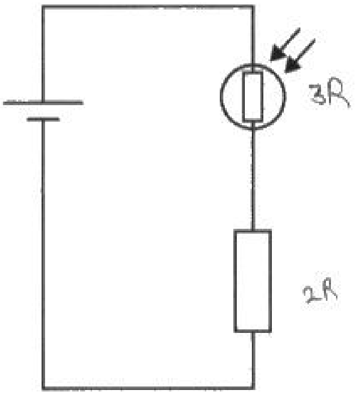
Where no unit is provided in the answer line then make sure to add one.

Question 16 (a)

This question presented a potential divider circuit in the context of a security lamp that was controlled by a light dependent resistor (LDR). Candidates were required to explain what effect decreasing the light intensity of the LDR would have on the potential difference across a fixed resistor. Candidates should have been aware that this would have increased the resistance of the LDR and that it would have taken a larger share of the potential difference. As a consequence the potential difference across the fixed resistor would have decreased. This was generally a well attempted question with the majority of responses indicating a sound understanding of the behaviour of LDR's and potential divider circuit.

16. A security lamp automatically switches on when the intensity of light incident on an LDR decreases.

Part of the electrical circuit in the security lamp is shown. The cell has negligible internal resistance.



(a) The light intensity incident on the LDR decreases.

Explain what happens to the potential difference across the fixed resistor.

(2)

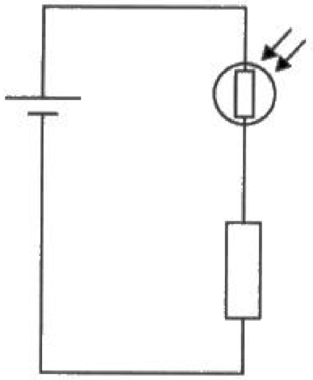
The p.d. accross the wire decreases as the resistance ~~me~~ of the LDR increases when lesser light is incident on it.

ResultsPlus
Examiner Comments

This response scored the first marking point but there was no reference to the fixed resistor and therefore the second marking point was not awarded. It is worth noting here that the second mark was dependent on the first mark being awarded.

16) A security lamp automatically switches on when the intensity of light incident on an LDR decreases.

Part of the electrical circuit in the security lamp is shown. The cell has negligible internal resistance.



(a) The light intensity incident on the LDR decreases.

Explain what happens to the potential difference across the fixed resistor.

(2)

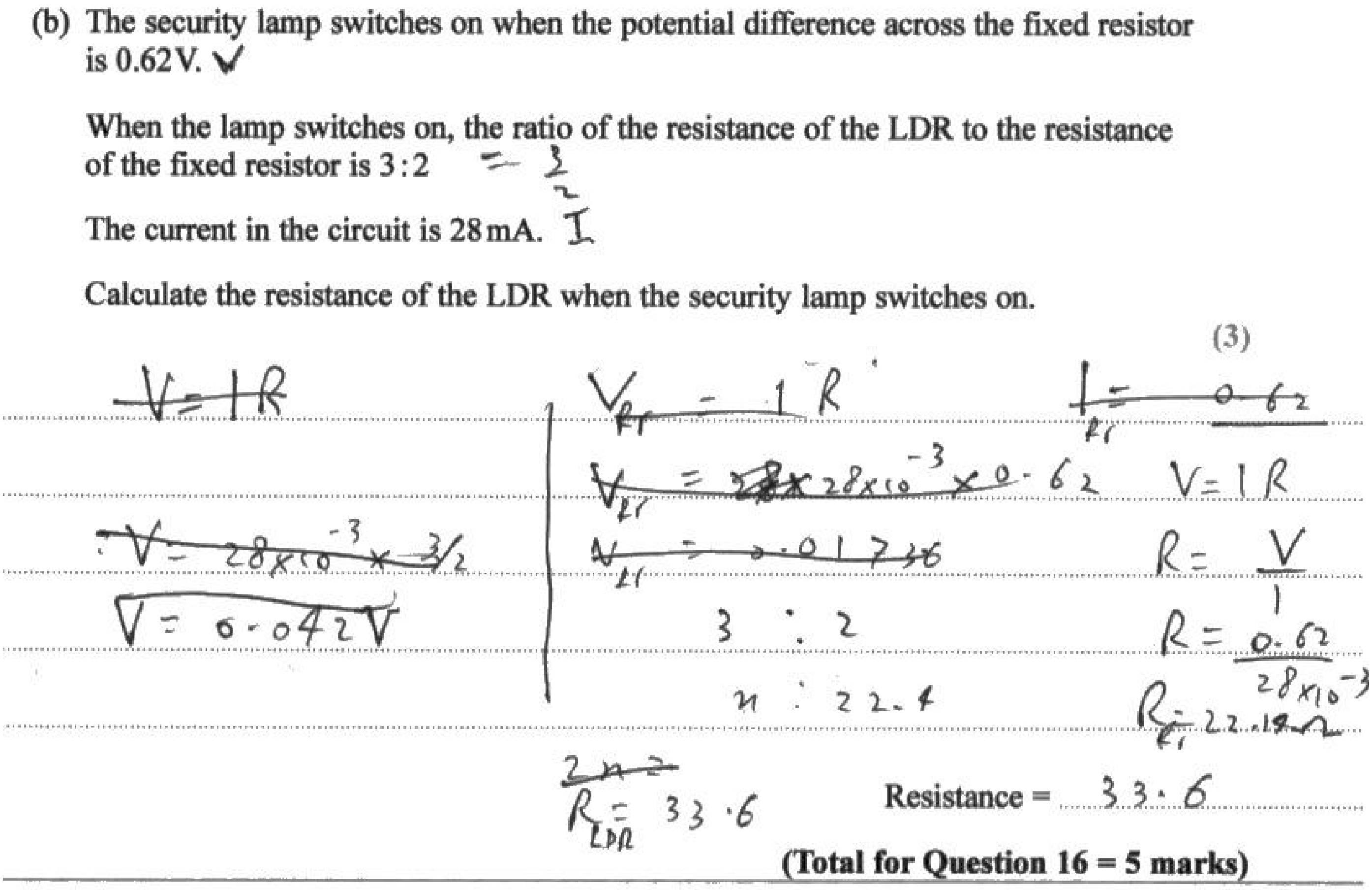
As the light intensity decreases, the resistance on LDR increases so the ratio changes and the potential difference across the fixed resistor ~~decre~~ decreases because the total current decreases and the resistance is fixed the potential difference across the resistor has to decrease

ResultsPlus
Examiner Comments

A good two mark response where the candidate clearly understands how the ratio of potential differences in the circuit is affected by the resistance of the components.

Question 16 (b)

Here candidates were provided with information about the current in the circuit as well as the ratio of resistances between the LDR and the fixed resistor. We are also told that the security lamp will switch on when the potential difference across the fixed resistor is 0.62V. Candidates were required to calculate the resistance of the LDR when the security lamp switches on. This question was very well answered with the majority of candidates scoring full marks.



(b) The security lamp switches on when the potential difference across the fixed resistor is 0.62V. ✓

When the lamp switches on, the ratio of the resistance of the LDR to the resistance of the fixed resistor is 3 : 2 $= \frac{3}{2}$

The current in the circuit is 28 mA. I

Calculate the resistance of the LDR when the security lamp switches on.

(3)

~~$V = IR$~~

~~$V = 28\times10^{-3} \times 3/2$~~

~~$V = 0\cdot042V$~~

~~$V_{R1} = IR$~~

~~$V_{R1} = 28\times10^{-3} \times 0\cdot62$~~

~~$V_{R1} = 0\cdot01736$~~

$3 : 2$

$x : 22.4$

~~$2x2$~~

$R_{LDR} = 33\cdot6$

~~$I_{R1} = 0\cdot62$~~

$V = IR$

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

$R = \frac{0\cdot62}{28\times10^{-3}}$

$R_{R1} = 22.14\Omega$

Resistance = 33·6

(Total for Question 16 = 5 marks)

ResultsPlus
Examiner Comments

This candidate used a ratio of resistances and calculated the correct value for the resistance. However, as was all too common in this paper, the candidate failed to provide the relevant unit for resistance, Ω.

(b) The security lamp switches on when the potential difference across the fixed resistor is 0.62 V.

When the lamp switches on, the ratio of the resistance of the LDR to the resistance of the fixed resistor is 3 : 2

The current in the circuit is 28 mA.

Calculate the resistance of the LDR when the security lamp switches on.

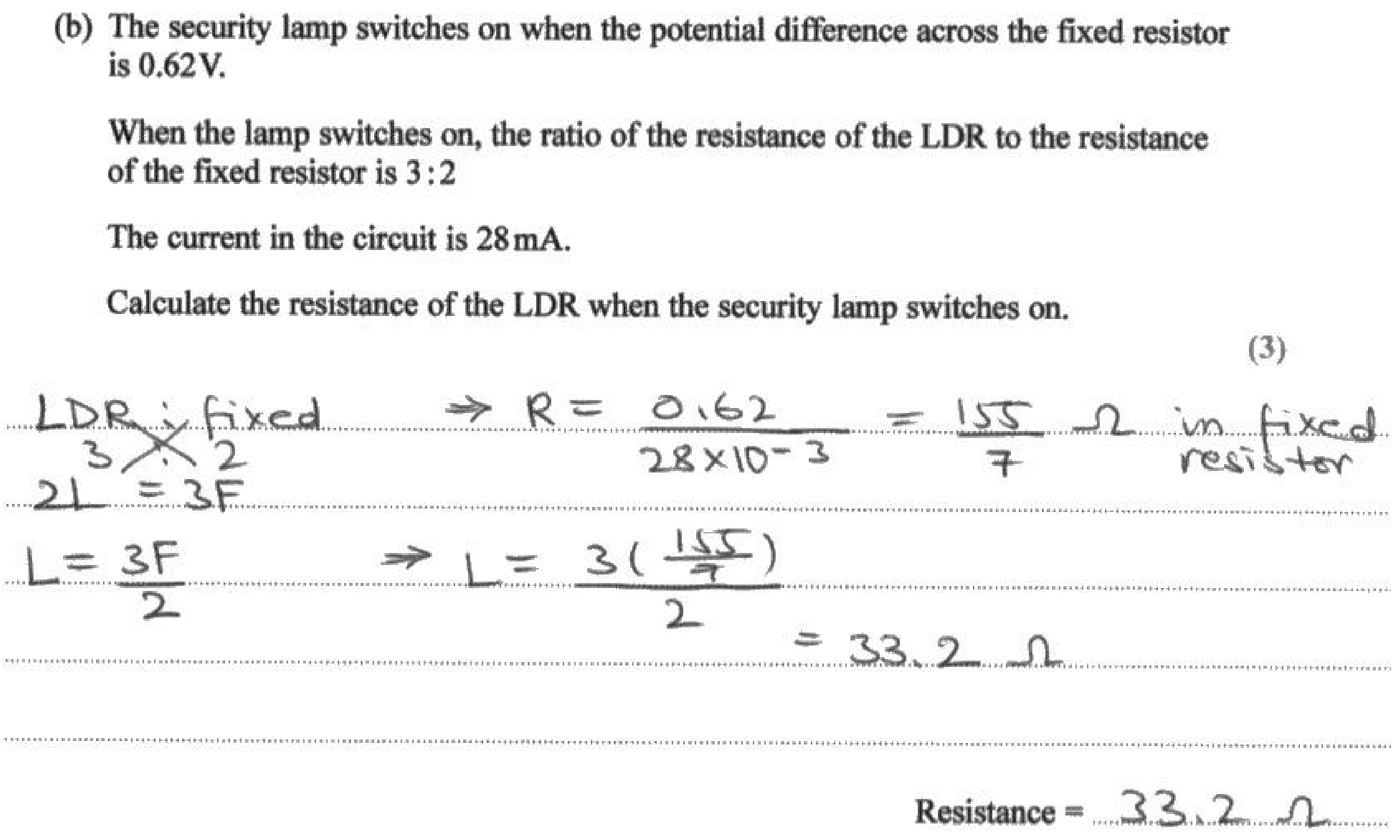
(3)

$V = I \times R$. $R = \frac{V}{I}$ $\frac{0.62}{28 \times 10^{-3}} = 22.14\,\Omega$

Resistance = 22

ResultsPlus
Examiner Comments

This candidate correctly calculated the resistance of the fixed resistor for the first marking point, however, no ratio was applied and so no further marks could be awarded.



(b) The security lamp switches on when the potential difference across the fixed resistor is 0.62 V.

When the lamp switches on, the ratio of the resistance of the LDR to the resistance of the fixed resistor is 3 : 2

The current in the circuit is 28 mA.

Calculate the resistance of the LDR when the security lamp switches on.

(3)

LDR : fixed $\rightarrow R = \dfrac{0.62}{28\times10^{-3}} = \dfrac{155}{7}\ \Omega$ in fixed resistor

3 : 2

$2L = 3F$

$L = \dfrac{3F}{2} \rightarrow L = \dfrac{3\left(\frac{155}{7}\right)}{2}$

$= 33.2\ \Omega$

Resistance = 33.2 Ω

ResultsPlus
Examiner Comments

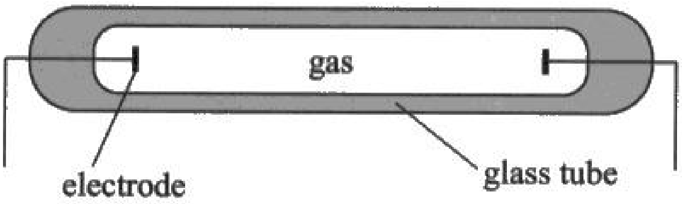
A common perfect three mark response where all steps of the calculation were clearly demonstrated.

Question 17 (a)

This was a straightforward question where the energy of a photon was provided and candidates were asked to calculate the frequency. Use of E = hf leading to f = E/h and correct substitution led to the correct value, which the vast majority of candidates achieved.

17 In the second half of the 19th century, scientists began to investigate interactions between photons and electrons.

(a) A discharge tube is a glass tube containing gas, as shown.



When the discharge tube is connected into an electrical circuit, the gas atoms emit photons. The photons have specific frequencies.

(i) One of the emitted photons has an energy of 3.44×10^{-19} J.

Calculate the frequency of this photon.

(2)

$h = 6.63 \times 10^{-34}$ $\qquad \frac{E}{h} = f$

$= 1.92 \times 10^{-15}$

Frequency of photon = ...

ResultsPlus
Examiner Comments

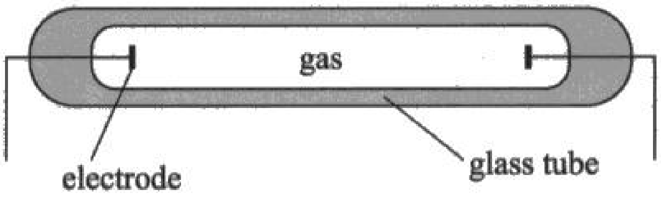
This candidate calculated a value but because there were no substitutions into the formula it was unclear how the answer was arrived at. No marks could be awarded.

ResultsPlus
Examiner Tip

In a question that requires the use of a formula make sure to substitute values into your equation.

17} In the second half of the 19th century, scientists began to investigate interactions between photons and electrons.

(a) A discharge tube is a glass tube containing gas, as shown.



When the discharge tube is connected into an electrical circuit, the gas atoms emit photons. The photons have specific frequencies.

(i) One of the emitted photons has an energy of 3.44×10^{-19} J.

Calculate the frequency of this photon.

(2)

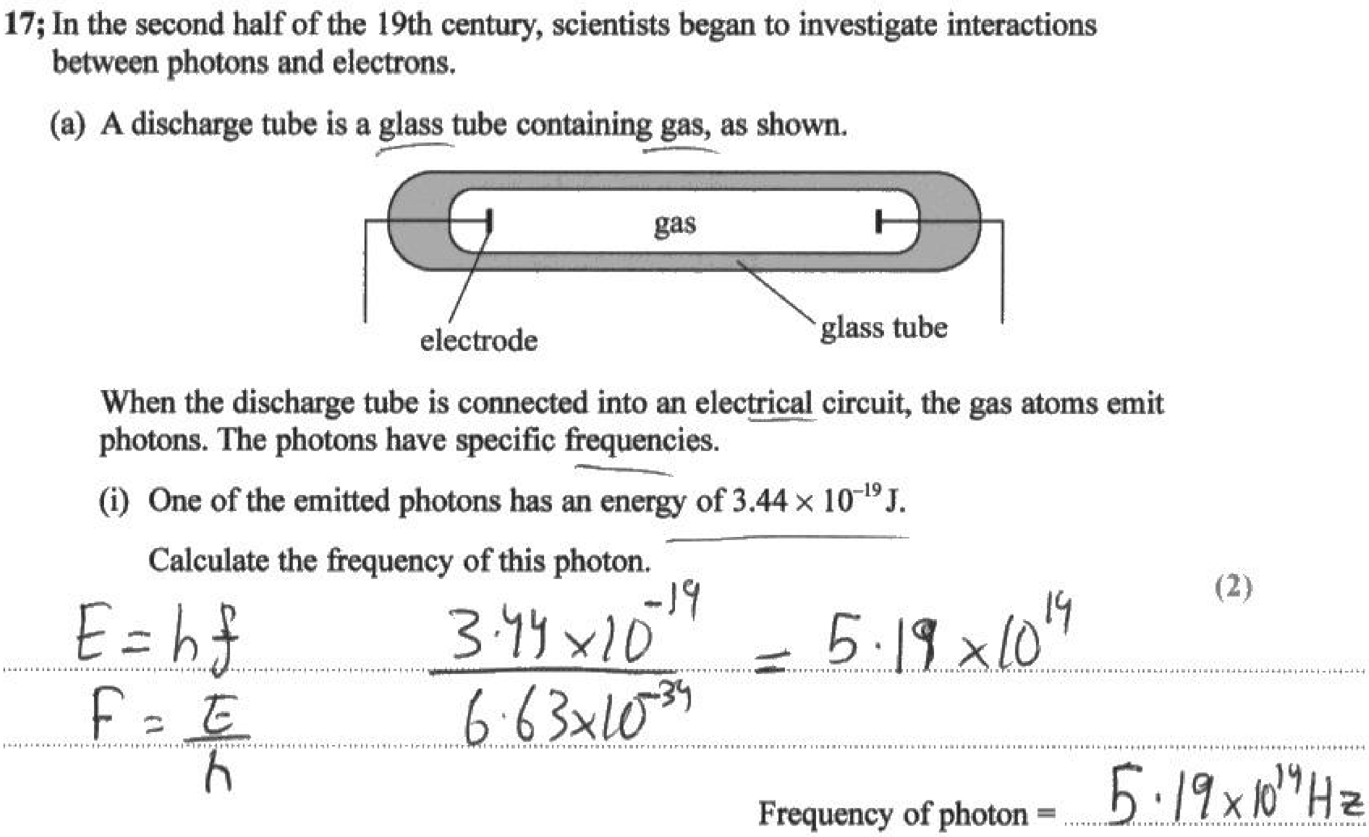
$E = hf$

$\frac{3{,}44 \times 10^{-19}}{6{,}63 \times 10^{-34}} = 5{,}1885 \times 10^{14}$

Frequency of photon = $5{,}19 \times 10^{14}$

ResultsPlus
Examiner Comments

Another example where the formula was used to calculate a correct value but the units were missing. Only the first marking point was awarded.



17 In the second half of the 19th century, scientists began to investigate interactions between photons and electrons.

(a) A discharge tube is a glass tube containing gas, as shown.

When the discharge tube is connected into an electrical circuit, the gas atoms emit photons. The photons have specific frequencies.

(i) One of the emitted photons has an energy of 3.44×10^{-19} J.

Calculate the frequency of this photon.

(2)

$E = hf$ $\qquad \frac{3.44 \times 10^{-19}}{6.63 \times 10^{-34}} = 5.19 \times 10^{14}$

$F = \frac{E}{h}$

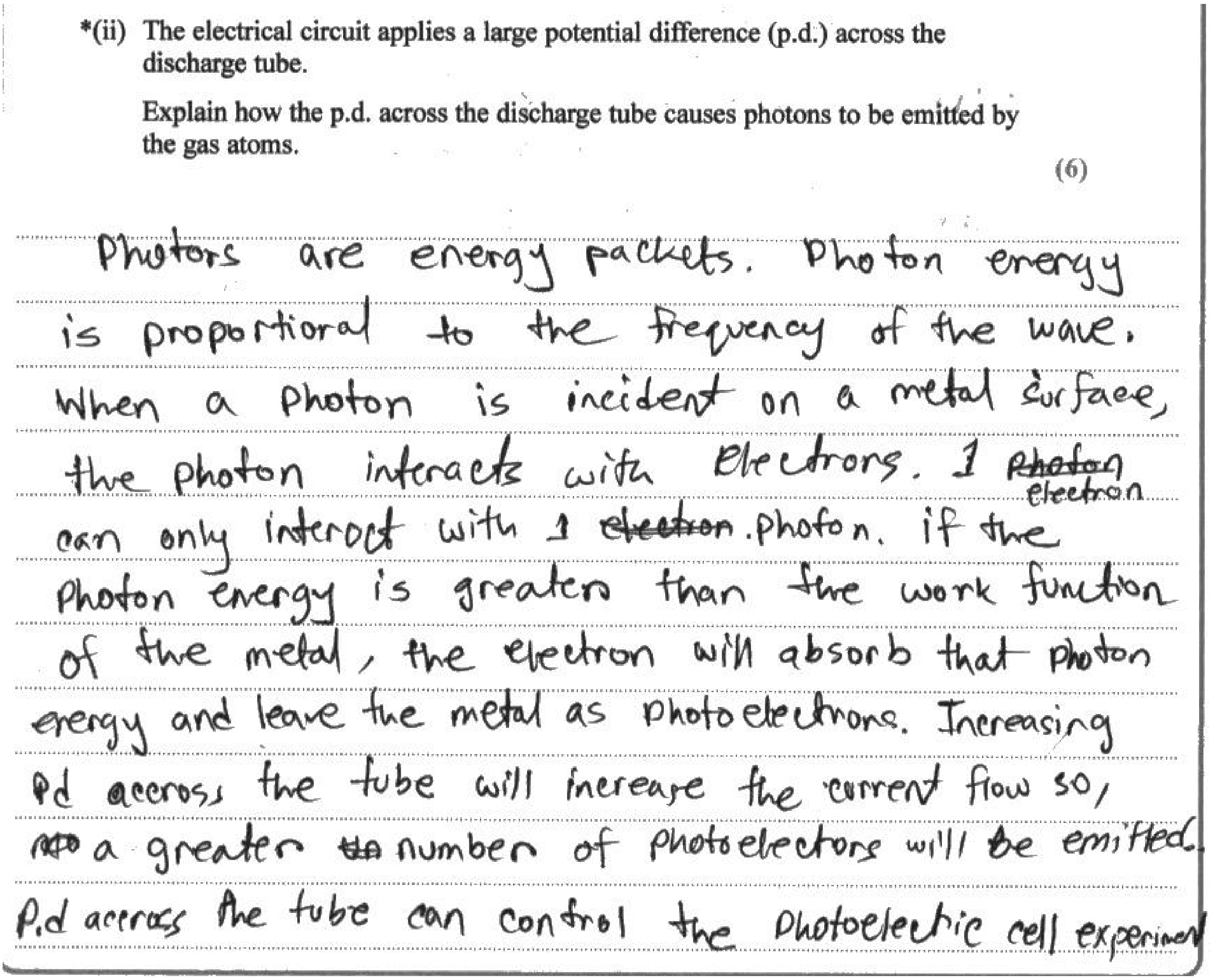
Frequency of photon = 5.19×10^{14} Hz

ResultsPlus
Examiner Comments

This was a very common textbook response.

Question 17 (a)(ii)

This was the indicative content question and, as in previous series, it often presents a variety of challenges to candidates. It was very pleasing to note, however, that candidates are beginning to attempt these questions with more effort and organisation is being put into responses. As always, there are six marking points here. Candidates are told that a large potential difference is applied across a discharge tube and that the tube emits photons. An explanation of how these photons were emitted was required. The first indicative content point was for recognising that the potential difference caused a current in the gas and this response was not commonly seen. The consequence of the current was to transfer energy to the gas atoms in the tube and this was seen slightly more often. The third and fourth indicative content marks were for explaining that the electrons would move up energy levels and emit photons when they fell back down. These two marking points were the most commonly awarded. The fifth indicative content mark was for linking photon energy to frequency and the final mark for recognising that there are discrete energy levels so only certain energy level differences are possible. The fifth mark was awarded more often than the sixth.



*(ii) The electrical circuit applies a large potential difference (p.d.) across the discharge tube.

Explain how the p.d. across the discharge tube causes photons to be emitted by the gas atoms.

(6)

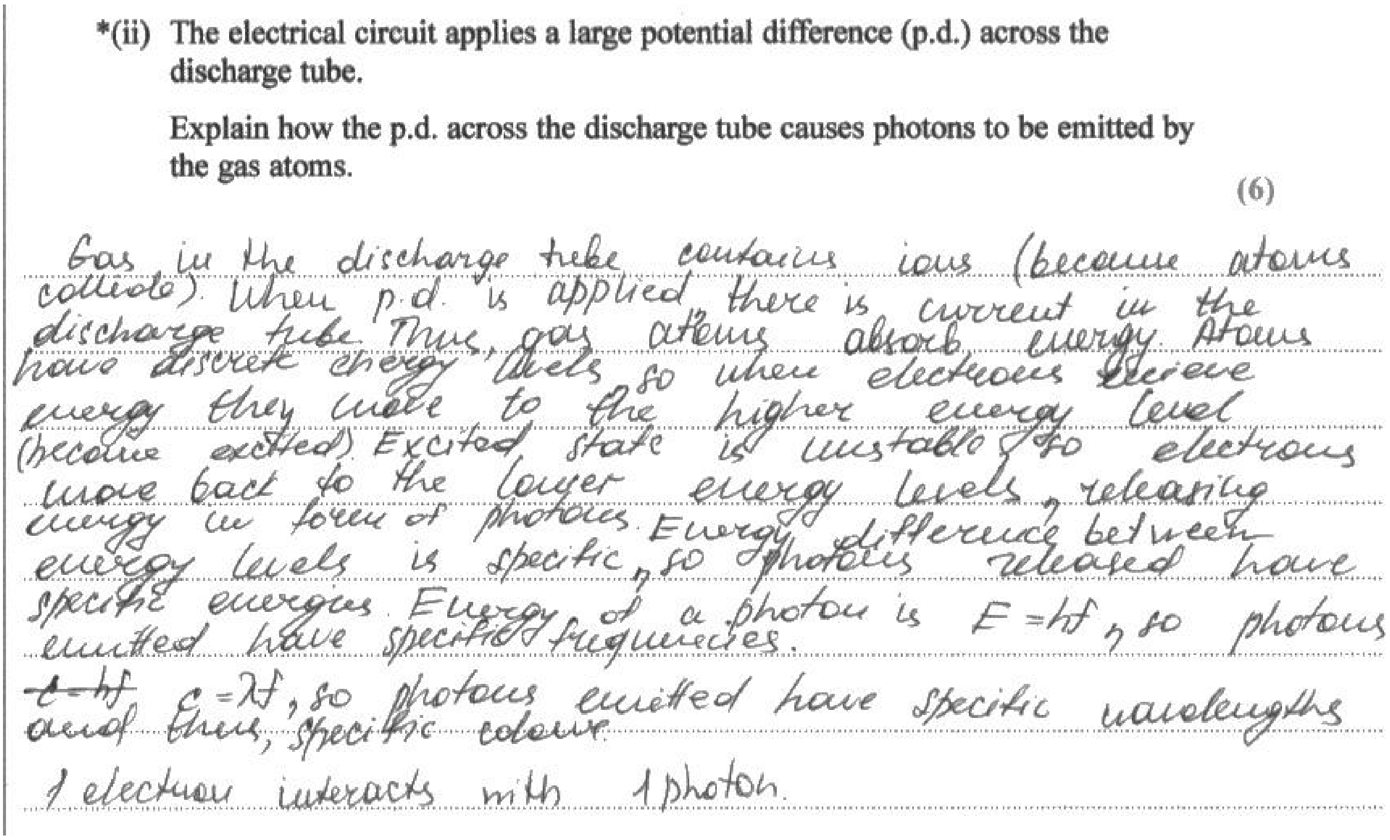
Photons are energy packets. Photon energy is proportional to the frequency of the wave. When a photon is incident on a metal surface, the photon interacts with Electrons. 1 ~~Photon~~ electron can only interact with 1 ~~electron~~ .photon. if the Photon energy is greater than the work function of the metal, the electron will absorb that photon energy and leave the metal as photoelectrons. Increasing Pd accross the tube will increase the current flow so, ~~no~~ a greater ~~the~~ number of photoelectrons will be emitted. P.d accross the tube can control the photoelectric cell experiment.

ResultsPlus Examiner Comments

This response scores the fifth indicative content mark only. It was quite common to see this kind of response where candidates are simply trying to describe the photoelectric effect, which was not relevant here.

ResultsPlus Examiner Tip

It is always important to read the context of the question and make sure that you are answering the question that is being asked.



*(ii) The electrical circuit applies a large potential difference (p.d.) across the discharge tube.

Explain how the p.d. across the discharge tube causes photons to be emitted by the gas atoms.

(6)

Gas in the discharge tube contains ions (because atoms collide). When p.d. is applied, there is current in the discharge tube. Thus, gas atoms absorb energy. Atoms have discrete energy levels, so when electrons receive energy they move to the higher energy level (become excited). Excited state is unstable & so electrons move back to the lower energy levels, releasing energy in form of photons. Energy difference between energy levels is specific, so photons released have specific energies. Energy of a photon is $E = hf$, so photons emitted have specific frequencies.

~~$E = hf$~~ $c = \lambda f$, so photons emitted have specific wavelengths and thus, specific colour.

1 electron interacts with 1 photon.

ResultsPlus
Examiner Comments

This was a well planned response that scored full marks. The candidate had clearly taken the time to consider the context and ordered the responses in the most logical way. The voltages leading to current then to energy transfer to the gas atoms. The electrons in the gas rising to a higher energy level and emitting a phon on return. The final two sentences linked the discreet nature of the energy transfer to a limited number of possible wavelengths.

Question 17 (b)(i)-(ii)

This was a two part question beginning with a calculation involving the photoelectric effect. Candidates were provided with the energy of the photons in electron volts along with the work function of the metal. They were then asked to show that the maximum velocity of emitted electrons was a certain value. This straightforward calculation was very well attempted with the vast majority of candidates scoring all three marks. The first mark required a conversion from electron volts to joules and this value had to be substituted into the Einstein equation for the second marking point. A correct rearrangement led to the third marking point.

In the second calculation the velocity value had to be used to calculate the de Broglie wavelength and this was a simple case of dividing the Planck constant by mass times velocity of the electron and this was again very well attempted.

(b) Photons with energy 4.75 eV are incident on a metal surface. These photons cause electrons to be emitted from the metal surface.

(i) Show that the maximum speed of the emitted electrons is about $5.3 \times 10^5\,\text{m}\,\text{s}^{-1}$.

work function of metal $= 6.30 \times 10^{-19}$ J

(3)

$Ekmax = \Phi + hf$

$\frac{1}{2}mv^2 =$

$\frac{1}{2} \times 9.11 \times 10^{-31} \times v^2 = 6.30 \times 10^{-19} + 4.75 \times 1.60 \times 10^{-19}$

$v^2 = \frac{6.30 \times 10^{-19} + 4.75 \times 1.60 \times 10^{-19}}{4.55 \times 10^{-31}}$

$v = 5.3 \times 10^5\ ms^{-1}$

(ii) Calculate the de Broglie wavelength of electrons moving at $5.3 \times 10^5\,\text{m}\,\text{s}^{-1}$.

(2)

$\lambda = \frac{h}{mv}$

$= \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \times 5.3 \times 10^5}$

$\lambda = 1.37 \times 10^{-9}$ m

de Broglie wavelength = 1.37×10^{-9} m

ResultsPlus
Examiner Comments

This is a good example of the importance of using the correct number of significant figures in a 'show that' question. This candidate did everything correctly but used the value 5.3 which was the same as that given in the question. The second part scored full marks.

(b) Photons with energy 4.75 eV are incident on a metal surface. These photons cause electrons to be emitted from the metal surface.

(i) Show that the maximum speed of the emitted electrons is about $5.3 \times 10^5\,\mathrm{m\,s^{-1}}$.

work function of metal = 6.30×10^{-19} J

(3)

$E_k = \cancel{hf - \phi} \quad \phi + \frac{1}{2}mv^2$

$4.75 \times 1.6 \times 10^{-19} = 6.3 \times 10^{-19} + \frac{1}{2} \times 9.11 \times 10^{-31} \times v^2$

$\Rightarrow v = 5.34 \times 10^{5}\ ms^{-1}$ (shown)

(ii) Calculate the de Broglie wavelength of electrons moving at $5.3 \times 10^5\,\mathrm{m\,s^{-1}}$.

(2)

$\lambda = \frac{h}{p} = \frac{6.63 \times 10^{-34}}{(9.11 \times 10^{-31}) \times (5.3 \times 10^{5})}$

$= 1.37 \times 10^{-9}\ m$

de Broglie wavelength = 1.37×10^{-9} m

ResultsPlus
Examiner Comments

This was a good example of a perfect response and happily this was often seen in this paper.

(b) Photons with energy 4.75 eV are incident on a metal surface. These photons cause electrons to be emitted from the metal surface.

(i) Show that the maximum speed of the emitted electrons is about $5.3 \times 10^5\,\mathrm{m\,s^{-1}}$.

work function of metal = 6.30×10^{-19} J

(3)

$E = 4.75 \times 10^{-19} \times 1.6 = 7.6 \times 10^{-19}$ J

$\frac{1}{2}mv^2 = (7.6 \times 10^{-19}) - (6.3 \times 10^{-19}) = 1.3 \times 10^{-19}$

$V = \sqrt{\frac{2 \times 1.3 \times 10^{-19}}{9.11 \times 10^{-31}}} = 5.342 \times 10^5$ ms^{-1}

(ii) Calculate the de Broglie wavelength of electrons moving at $5.3 \times 10^5\,\mathrm{m\,s^{-1}}$.

(2)

$\lambda = \frac{6.63 \times 10^{-34}}{5.342 \times 10^5 \times 9.11 \times 10^{-31}} = $ ~~1.36×10^{-9}~~

1.37×10^{-9}

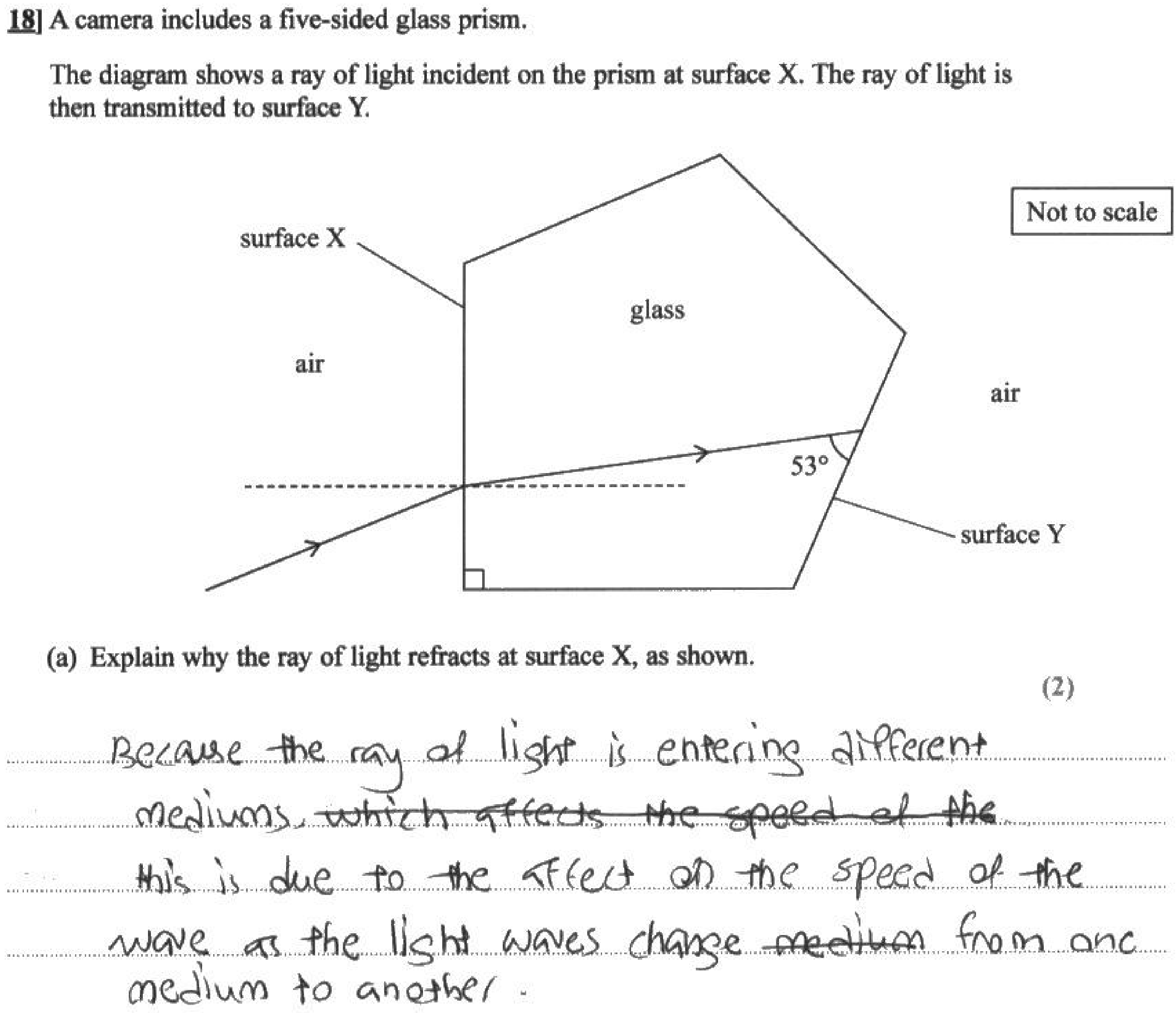
de Broglie wavelength = 1.37×10^{-9}

ResultsPlus
Examiner Comments

This was a very common response to the first part where the conversion of electron volts to joules was completed first and correctly substituted into the equation. The correct value was calculated. As this was a 'show that' question the answer needed to be at least one more significant figure than the value given and there was no unit penalty. Unfortunately this candidate performed a correct calculation for the second part but failed to provide a unit, scoring only the first marking point.

Question 18 (a)

This first part of question 18 provided a diagram of a ray of light entering a camera lens and clearly being diffracted. The refracted ray was incident on surface Y at an angle of 53°. Candidates were asked to explain why the ray refracted upon entering the lens. It should have been evident that the ray of light was moving from a less dense to a more dense region and would therefore be travelling at a lower speed in the glass. Most candidates answered this question well but some responses were lacking in detail and scored no marks.



18 A camera includes a five-sided glass prism.

The diagram shows a ray of light incident on the prism at surface X. The ray of light is then transmitted to surface Y.

(a) Explain why the ray of light refracts at surface X, as shown.

(2)

Because the ray of light is entering different mediums. ~~which affects the speed of the~~ this is due to the affect on the speed of the wave as the light waves change ~~medium~~ from one medium to another.

ResultsPlus
Examiner Comments

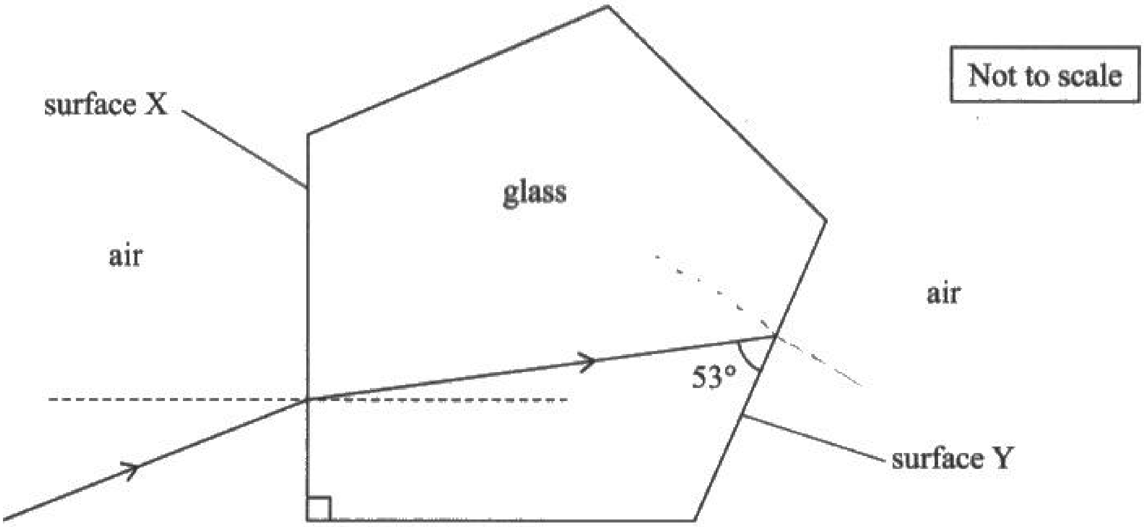
This candidate clearly has some awareness that the speed of light would not be the same in different media but just made a simple statement that the speed would change rather than reduce and therefore scored zero.

ResultsPlus
Examiner Tip

When describing a difference use comparative statement such as greater or smaller rather than a simple statement such as changes.

18 A camera includes a five-sided glass prism.

The diagram shows a ray of light incident on the prism at surface X. The ray of light is then transmitted to surface Y.



(a) Explain why the ray of light refracts at surface X, as shown.

(2)

as ray of light travels from one medium to another, the speed of the ray of light changes (decreases) due to the change in density of medium. causes the direction of ray of light to change and bend towards medium

ResultsPlus
Examiner Comments

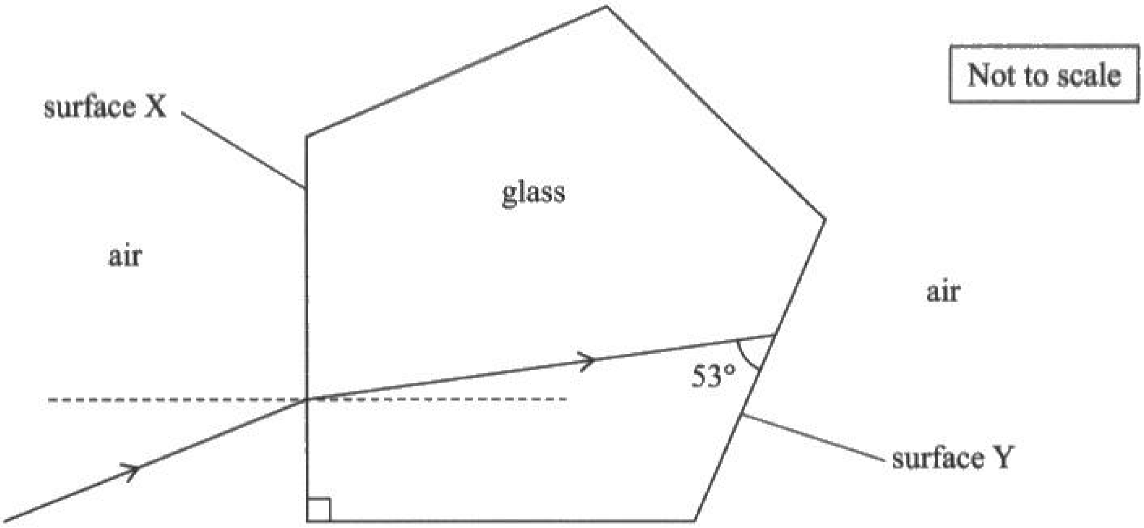
This candidate had the right idea but lacked the necessary comparators. The first marking point was awarded as the word decrease was added to the first sentence. However, rather than stating the density increased this response simply referred to density changing and so failed to score the second marking point.

Question 18 (b)

In this question candidates were told that if the ray of light entering the lens did not totally internally reflect then it could be made to do so by adding a layer of silver to surface Y. It was necessary to deduce whether or not the layer of silver needed to be added. There were two ways of approaching this but in either case it was necessary to carry out a calculation to establish whether or not total internal reflection would occur. The most straightforward method was to use the equation sin C = 1/n and compare the critical angle with the angle of incidence. As the angle of incidence was less than the critical angle then total internal reflection would not take place and therefore a layer of silver was needed. The second method was to use the Snell's law equation and calculate the angle of refraction which would have shown that the ray did indeed refract and therefore total internal reflection would not take place and so a layer of silver was needed. This question was poorly attempted by many candidates by virtue of the fact that many thought that the angle of incidence was 53 degrees.

18] A camera includes a five-sided glass prism.

The diagram shows a ray of light incident on the prism at surface X. The ray of light is then transmitted to surface Y.



(b) At surface Y the ray of light must be reflected.

This reflection could be due to total internal reflection.

If the ray of light is not totally internally reflected, the light can be made to reflect by applying a layer of silver to surface Y.

Deduce whether a layer of silver is needed on surface Y.

refractive index of glass used to make prism = 1.52

(4)

$\sin C = \frac{1}{n}$

~~so~~ $C = \sin^{-1}\left(\frac{1}{n}\right)$

$C = \sin^{-1}\left(\frac{1}{1.52}\right)$

$C = 41.14° < 53°$ so the layer of silver is not needed *

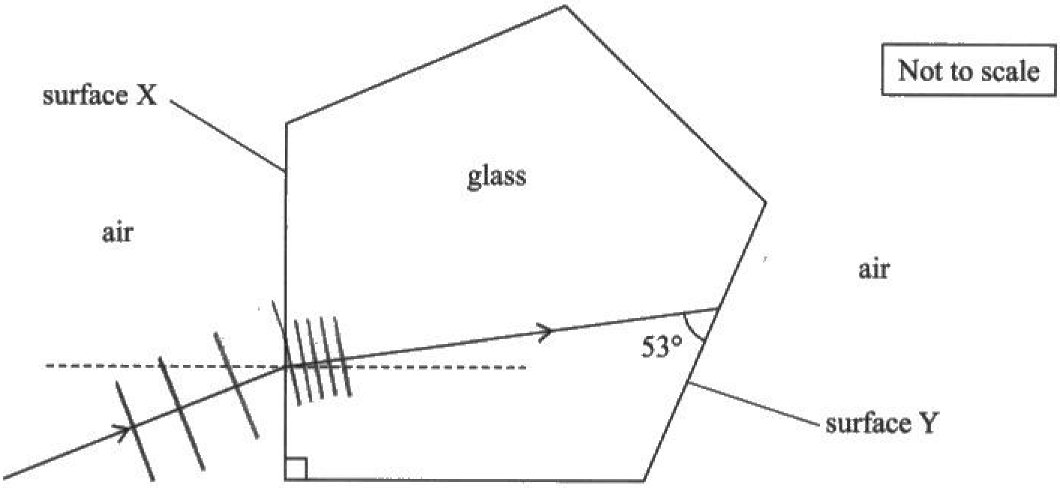
* as the angle at which light tries to escape is ~~the~~ more than the critical angle, so there will be TIR

ResultsPlus
Examiner Comments

This was a common response where the candidate was awarded the first two marking points for the correct calculation of that critical angle, however, 53 degrees was incorrectly stated as the critical angle and no further marks were awarded.

18) A camera includes a five-sided glass prism.

The diagram shows a ray of light incident on the prism at surface X. The ray of light is then transmitted to surface Y.



(b) At surface Y the ray of light must be reflected.

This reflection could be due to total internal reflection.

If the ray of light is not totally internally reflected, the light can be made to reflect by applying a layer of silver to surface Y.

Deduce whether a layer of silver is needed on surface Y.

refractive index of glass used to make prism = 1.52

(4)

$n_{glass} \sin\theta_{glass} = n_{air} \sin\theta_{air}$.

$1.52 \times \sin 37° = 1.00 \times \sin\theta_{air}$

$\sin\theta_{air} = 0.915$ θ_{air} is less than 90° since its sin is less than 1.

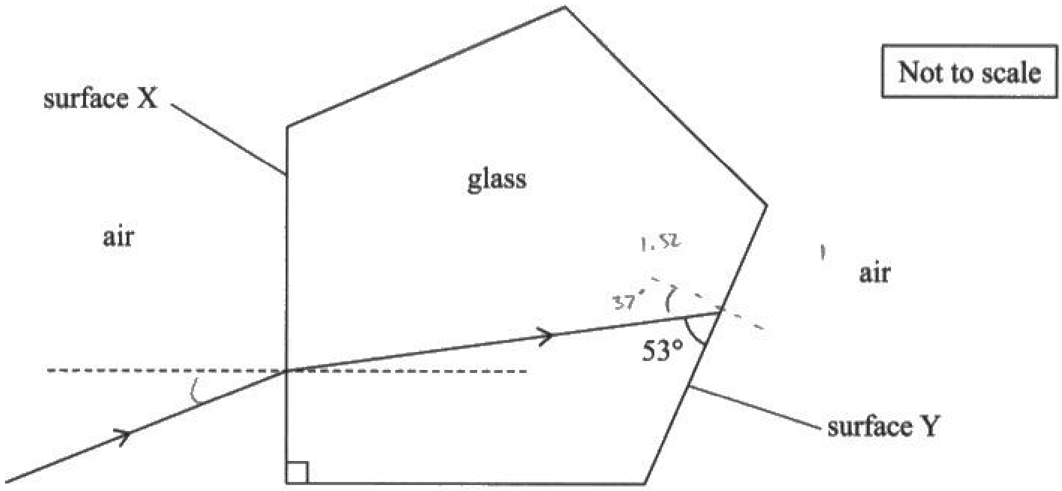
Total internal reflection won't occur. The silver layer isn't needed

ResultsPlus
Examiner Comments

This candidate started with the use of Snell's law but failed to calculate an angle. This was deemed worthy of only the first marking point but would have scored the second had the calculated number been converted to an angle. The conclusion here was incorrect.

18 A camera includes a five-sided glass prism.

The diagram shows a ray of light incident on the prism at surface X. The ray of light is then transmitted to surface Y.



(b) At surface Y the ray of light must be reflected.

This reflection could be due to total internal reflection.

If the ray of light is not totally internally reflected, the light can be made to reflect by applying a layer of silver to surface Y.

Deduce whether a layer of silver is needed on surface Y.

refractive index of glass used to make prism = 1.52

(4)

$90 - 53 = 37°$

$Q_I = 37°$

$n = \frac{1}{\sin C}$

$\sin C \times n = 1$

$\sin C = 25/38$

$C = 41.1°$

$Q_I < Q_c$

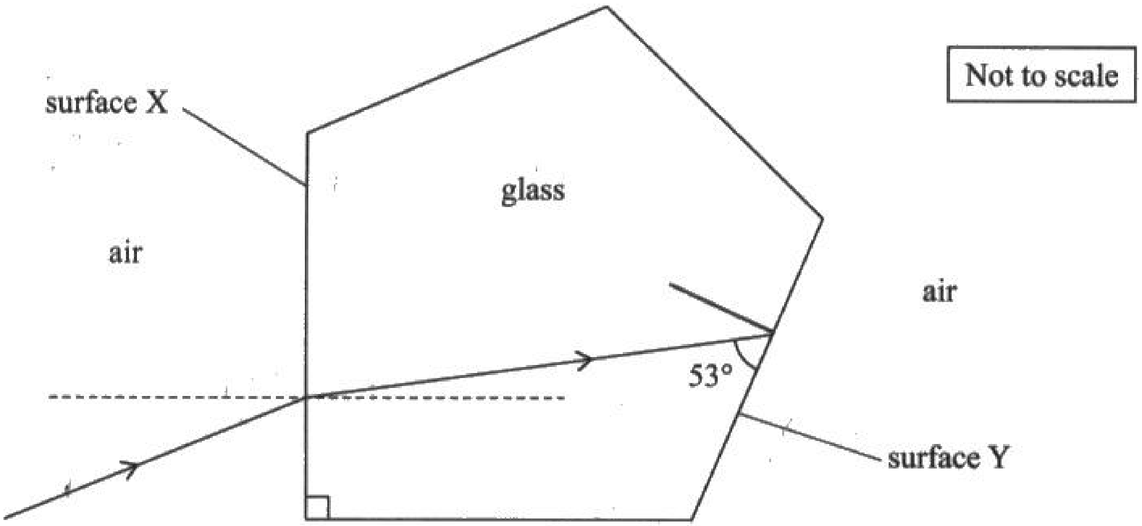
∴ a layer of silver is required.

ResultsPlus
Examiner Comments

This was a common response and scored the first three marking points. The candidate calculated the correct critical angle and stated that the angle of incidence was less than the critical angle, however, there was no statement that total internal reflection would not take place and therefore the fourth marking point was withheld.

18 A camera includes a five-sided glass prism.

The diagram shows a ray of light incident on the prism at surface X. The ray of light is then transmitted to surface Y.



(b) At surface Y the ray of light must be reflected.

This reflection could be due to total internal reflection.

If the ray of light is not totally internally reflected, the light can be made to reflect by applying a layer of silver to surface Y.

Deduce whether a layer of silver is needed on surface Y.

refractive index of glass used to make prism = 1.52

(4)

$\sin c = \frac{1}{n}$ $\quad c = \sin^{-1}\left(\frac{1}{1.52}\right) = 41^{0}$

angle = 90 - 53 (not to the normal) = 37

37 < 41 therefore no total internal reflection

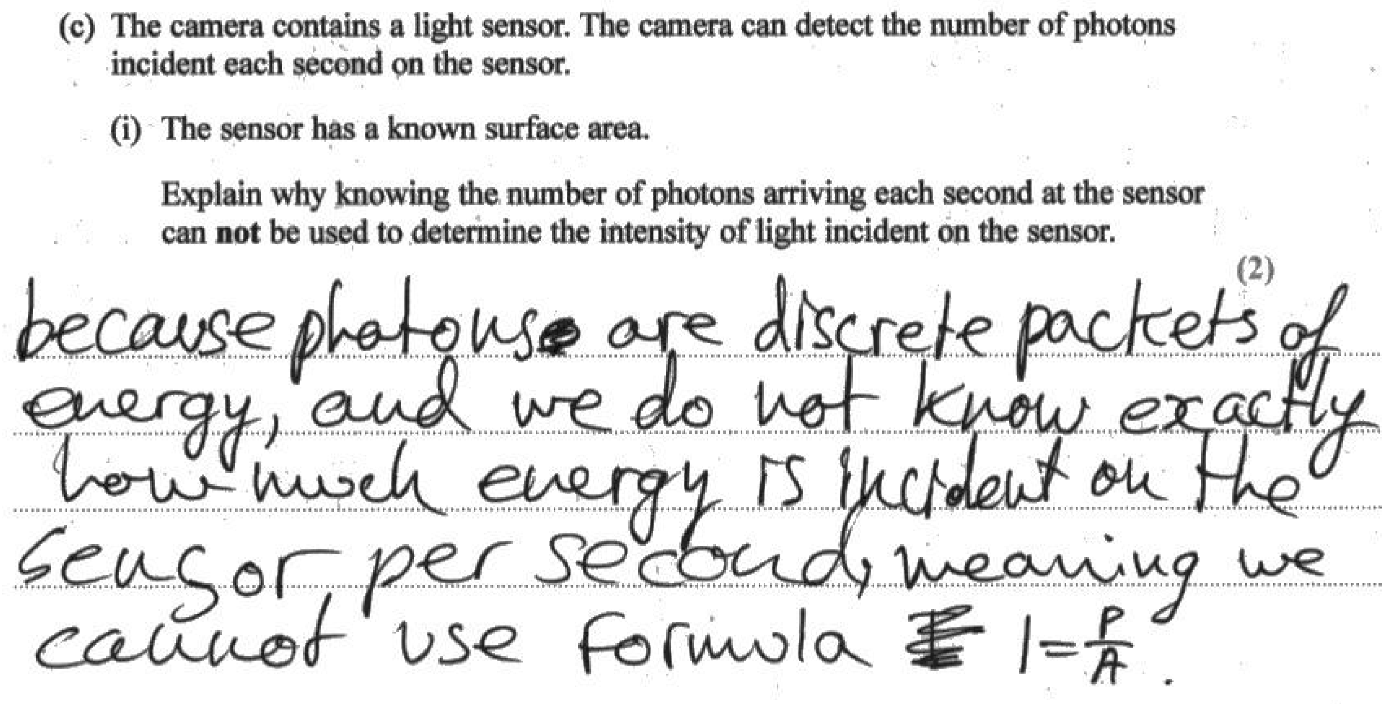
so silver layer to Y is needed

ResultsPlus
Examiner Comments

This was a concise and fully correct response that was seen often.

Question 18 (c)(i)

This question required candidates to explain why knowing the number of photons incident on a sensor of known surface area was not sufficient to enable the calculation of intensity. It was expected that candidates would recognise that to calculate the intensity it would have been necessary to know the energy of each photon and link this to I = P/A. As frequency of the incident light was not known then the energy of the photon could not be determined. Very few candidates were awarded a mark here.



(c) The camera contains a light sensor. The camera can detect the number of photons incident each second on the sensor.

(i) The sensor has a known surface area.

Explain why knowing the number of photons arriving each second at the sensor can **not** be used to determine the intensity of light incident on the sensor.

(2)

because photons are discrete packets of energy, and we do not know exactly how much energy is incident on the sensor per second, meaning we cannot use formula $I = \frac{P}{A}$.

ResultsPlus

Examiner Comments

With a little more detail this candidate could have scored marks but they scored zero. There is no mention of photon energy not being known and although the formula for intensity was correctly written the terms were not defined.

(c) The camera contains a light sensor. The camera can detect the number of photons incident each second on the sensor.

(i) The sensor has a known surface area.

Explain why knowing the number of photons arriving each second at the sensor can **not** be used to determine the intensity of light incident on the sensor.

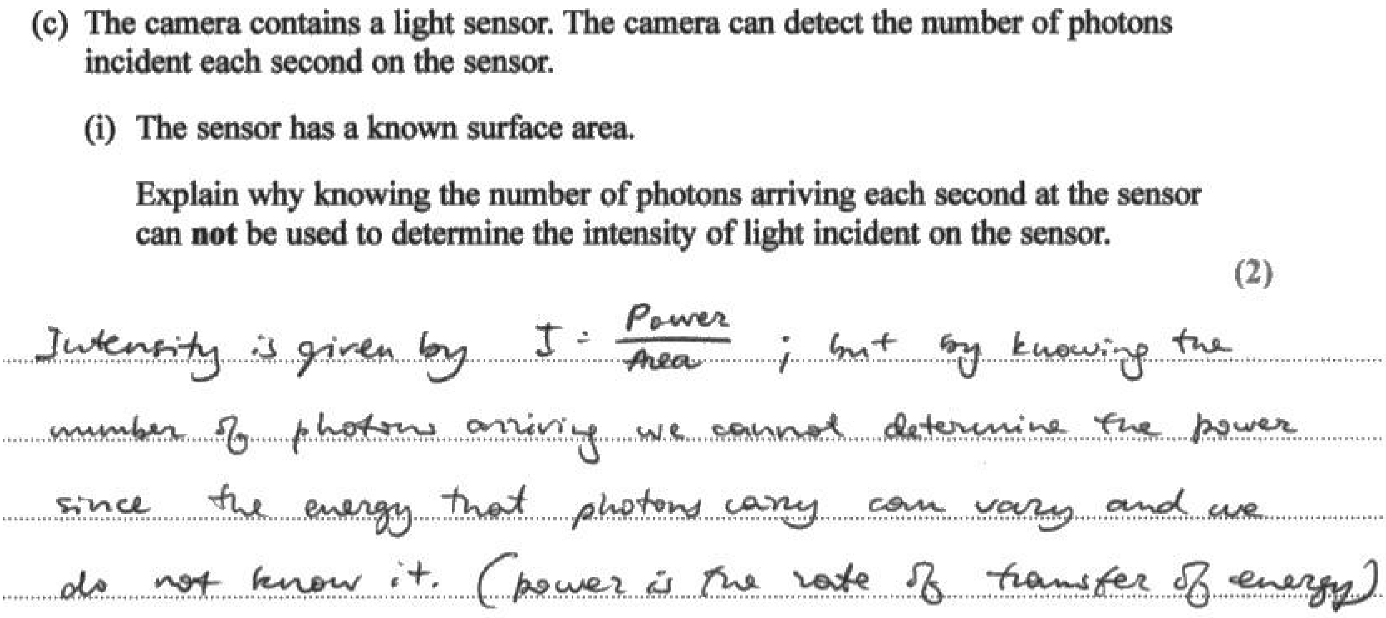
(2)

$$\text{Intensity} = \frac{\text{Power}}{\text{Area}}$$

Number of photons doesn't give us the power

ResultsPlus
Examiner Comments

This response was awarded the first marking point for simply defining the terms of the intensity equation.



(c) The camera contains a light sensor. The camera can detect the number of photons incident each second on the sensor.

(i) The sensor has a known surface area.

Explain why knowing the number of photons arriving each second at the sensor can **not** be used to determine the intensity of light incident on the sensor.

(2)

Intensity is given by $I = \frac{Power}{Area}$; but by knowing the number of photons arriving we cannot determine the power since the energy that photons carry can vary and we do not know it. (power is the rate of transfer of energy)

ResultsPlus

Examiner Comments

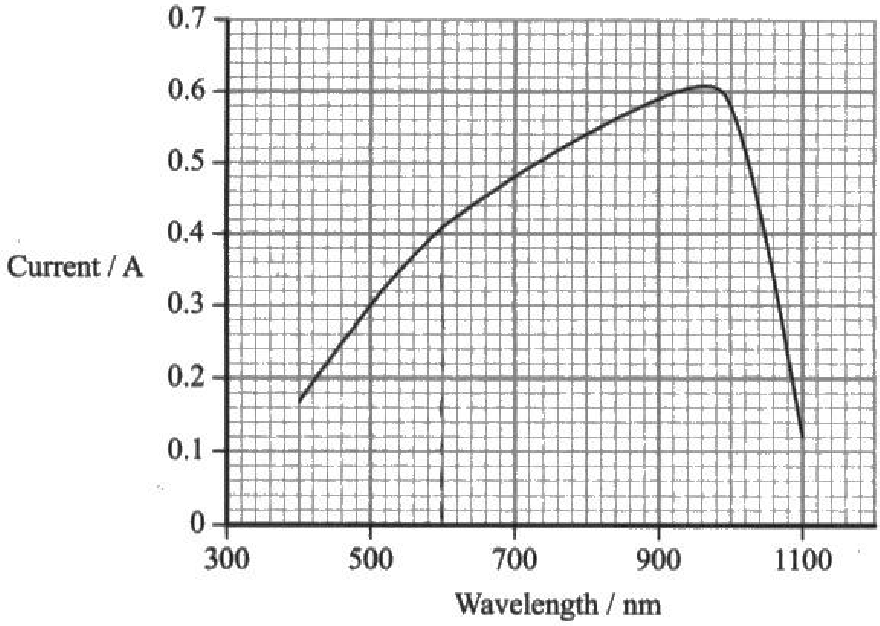
A very rarely seen two mark response where the candidate clearly made the link between energy and power and how the inability to calculate energy meant that the intensity equation could not be used as power could not be calculated.

Question 18 (c)(ii)

This was quite a challenging question in which candidates had to calculate the percentage of photons that were detected on a sensor. The wavelength of the incident light was provided and this could be used to read a value for current from the graph provided, as well as calculating the energy of a photon of this light. The current value should have been used to calculate the number of electrons passing a point per second. The power of the light was also provided and this should have been used to calculate the number of photons incident on the sensor. The ratio of number of electrons to number of photons would have given the percentage of photons detected. Most candidate could read a value for current from the graph although no mark was awarded for this. The majority of candidates could calculate the photon energy for the first two marking points but this was as far as most candidates could progress. Interestingly, there were many unexpected ways that candidates attempted to answer this question involving circuit power equations. Technically speaking, this was an incorrect way of doing this but full credit was given to responses that produced a percentage within the accepted range.

(ii) Light incident on the sensor causes a current in a circuit in the camera.

Light with a power of 1.0 W is incident on the sensor. The graph shows the relationship between the wavelength of the light and the current produced.



The current is proportional to the number of photons detected per second.

Monochromatic light with a wavelength of 600 nm is incident on the sensor. The power of the light is 1.0 W.

Determine the percentage of photons that are detected by the sensor.

(5)

$I = \frac{P}{A}$ $E = hf$ $E = h\frac{v}{\lambda}$

$E = (6.63\times10^{-34})\left(\frac{3\times10^{8}}{600\times10^{-9}}\right) = 3.315\times10^{-19}$ J

$\frac{1\,W}{3.51\times10^{-19}\,W}$ = ~~2.849×10^{18}~~

$\frac{3.51\times10^{-19}\,J}{1\,second}$

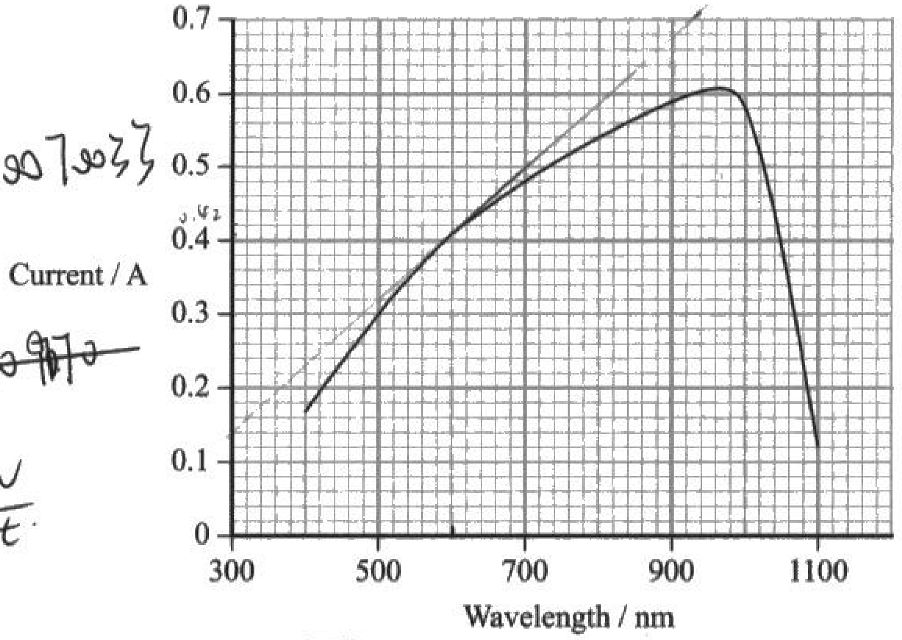
$= 3.51\times10^{-19}$ W

ResultsPlus
Examiner Comments

This candidate scored the first two marking points for the calculation of photon energy by combining the equations v = fλ and E = hf. It appears that there was a transcription error but had the candidate put the 1W by the energy value then the third marking point would have been awarded.

(ii) Light incident on the sensor causes a current in a circuit in the camera.

Light with a power of 1.0 W is incident on the sensor. The graph shows the relationship between the wavelength of the light and the current produced.



0.0007003

~~0.000970~~

$P = \frac{W}{t}$

The current is proportional to the number of photons detected per second.

Monochromatic light with a wavelength of 600 nm is incident on the sensor.
The power of the light is 1.0 W.

Determine the percentage of photons that are detected by the sensor.

(5)

when $\lambda = 600$ nm I: current ≈ 0.41 A $I = kn$

$I = nqVA$ $n = \frac{I}{qVA}$ number of photons = number of electrons.

$E = hf$ $c = f\lambda$ $f = \frac{c}{\lambda}$ $E = 3.315 \times 10^{-19}$ J

$P = \frac{W}{t}$ $W = 1$ J Number of incident light = $3.016591252 \times 10^{18}$

$\lambda = \frac{h}{p} = \frac{h}{mv}$ $V = \frac{h}{\lambda m}$ = ~~$8.2443438911 \times 10^{-4}$~~ 1212.952799

$A = 1$ $n = \frac{I}{qVA}$ = ~~$3.108191548 \times 10^{21}$~~ $2.112613122 \times 10^{15}$

% = ~~0.0009~~ ~~0.097%~~ 0.07%

0.07%

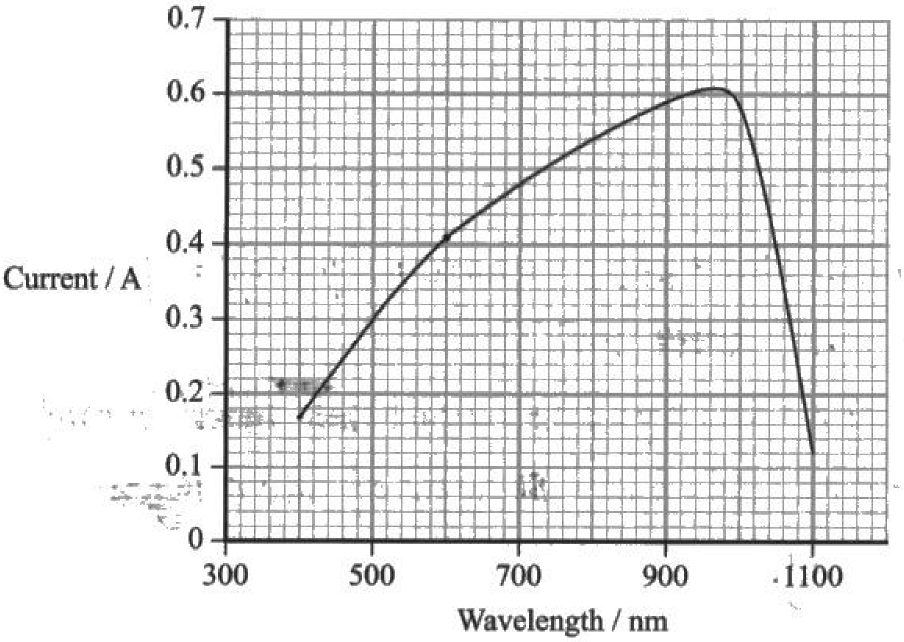
Percentage of photons detected = ~~0.97%~~

ResultsPlus
Examiner Comments

This response scored the first two marking points on the third line and the third marking point on the fourth line. After that there was a great deal of confusion and the concept of momentum was incorrectly introduced. Interestingly, although the correct value for current was read from the graph it was not used.

(ii) Light incident on the sensor causes a current in a circuit in the camera.

Light with a power of 1.0 W is incident on the sensor. The graph shows the relationship between the wavelength of the light and the current produced.



The current is proportional to the number of photons detected per second.

Monochromatic light with a wavelength of 600 nm is incident on the sensor. The power of the light is 1.0 W.

Determine the percentage of photons that are detected by the sensor.

(5)

When wavelength = 600 nm , $I = 0.41$ A

Photon number in light: $v = f\lambda$ $f = \frac{3\times10^8}{6\times10^{-7}} = 5\times10^{14}$ Hz

$E = hf = 3.31\times10^{-19}$ J   number: $1 \div 3.31\times10^{-19} = 3.02\times10^{18}$

$I = Qt$ number of electrons: $0.41 \div 1.6\times10^{-19} = 2.56\times10^{18}$

Since ~~the~~ one electron would only be able to absorb one photon at a time for exitation, the number of electrons released would be same as the amount of photons detected.

percentage: $\frac{2.56\times10^{18}}{3.02\times10^{18}} = 84.85\%$

Percentage of photons detected = 84.85%

ResultsPlus
Examiner Comments

A very well organised and logical full mark response. The current was correctly read from the graph and then the photon energy calculated. The power was divided by the photon energy to give the correct number of photons produced. Q = It with the current from the graph gave the correct number of electrons released and this was used to calculate the correct percentage.

Paper Summary

Based on their performance on this paper, candidates should:

- Always remember to include relevant units in calculation questions.
- Make sure that in 'show that' questions, one more significant figure is added.
- When making comparisons as in question 18(a), use language such as larger or smaller rather than different.
- Always show the numbers you are substituting into calculations as these could gain credit where a wrong answer is provided.
- When answering indicative content questions try to form a logical structure to your answers before writing anything down.
- When using equations to help explain concepts always define the terms of the equation.