Examiners' Report
June 2023

International Advanced Level Physics WPH12 01

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 8 longer answer questions which consisted of short open responses, calculations and some extended written answers. Questions 12 and 18 were both related to Core Practical activities that students undertake as part of the IAL course. This unit always contains one 6 mark linkage question, which on this occasion was about the variation of power within a circuit containing a light dependent resistor.

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 challenging.

Although Section A was generally completed very well by most students, there were 3 of the multiple choice questions where less than half of the candidates answered them correctly. The first of these was question 6 which was testing the link between path difference and phase difference of waves. Question 8 was practical-based, revolving around measurements taken during a diffraction grating experiment. Candidates are often confused about the terms used in the equation for diffraction gratings, and often get it confused with the equation for double-slit interference (even though that equation is not on this specification). Question 9 was an unusual twist on the equation for intensity related to distance from a point source of radiation.

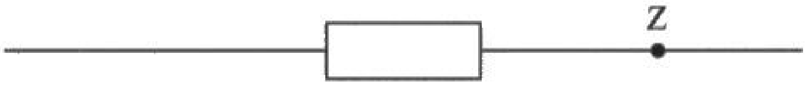
Question 11

This is a two-part question, both calculations, where the answer for part (a) might be needed for part (b). Hence part (a) is a "show that" question, where you are given the expected answer so that it can be used for part (b) if the candidate has not been able to correctly answer part (a).
For "show that" questions, there are two golden rules:

1) Show the answer to at least one more significant figure than the value given (in the case of this question, that means 1.28A instead of 1.3A)
2) Always show all of the numbers used in calculations, so it is clear that you have used the correct method to achieve the answer.

Generally speaking, both parts of this question were answered very well, with more than 80% of candidates achieving full marks on (a), and more than 65% of candidates achieving full marks on (b).

11 Part of an electrical circuit is shown.



In 60 seconds, 4.80×10^{20} electrons pass point Z.

(a) Show that the current at Z is about 1.3 A.

(3)

$I = \frac{\Delta Q}{\Delta t} = \frac{78}{60} = 1.3A$

(b) In 60 seconds, the resistor transfers 24 J of energy.

Calculate the potential difference across the resistor.

(2)

$V = \frac{W}{Q} \quad \frac{24}{78} = \frac{4}{13}$

Potential difference = $4/13$

ResultsPlus
Examiner Comments

(a) This candidate appears to have completed a backwards calculation in order to find the total charge required in order to result in a current of 1.3A. The first thing to notice is that the answer is not given to any more significant figures than the "show that" value given, so they do not score MP3. We also do not see any calculation to calculate the total charge (using the number of electrons given in the question). So it also does not score MP1. However, they have used the equation to calculate current from charge and time, so score MP2.

(b) Having established that the total charge is 78 C from part (a), this candidate then correctly substitutes into the equation to calculate potential difference. If this had been represented as a decimal and with units on the end, it would have scored both marks, but leaving the answer as a fraction does not allow MP2 to be awarded, even if the units had been there.

ResultsPlus
Examiner Tip

In physics examinations, answers should not be left as fractions, surds, recurring decimals or in factors of pi.

11 Part of an electrical circuit is shown.

In 60 seconds, 4.80×10^{20} electrons pass point Z.

(a) Show that the current at Z is about 1.3 A.

(3)

$I = \frac{Q}{t} = \frac{4.80 \times 10^{20} \times 1.6 \times 10^{-19}}{60}$

$= 1.28\ A$

约 $1.3\ A$

(b) In 60 seconds, the resistor transfers 24 J of energy.

Calculate the potential difference across the resistor.

(2)

~~P/t=~~ $Q = EV$

$V = \frac{Q}{E} = \frac{4.80 \times 10^{20} \times 1.6 \times 10^{-19}}{24}$

$= 3.2\ V$

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

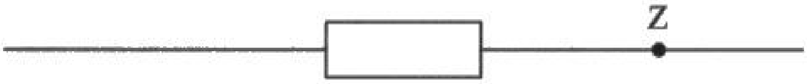
Potential difference = 3.2 V

ResultsPlus
Examiner Comments

(a) This candidate has a fully-correct all in one calculation to achieve the correct answer of 1.28A. The comparison with 1.3A is not necessary, but it always considered good practice.

(b) The candidate has incorrectly quoted and rearranged the equation to find potential difference. Although the numbers they insert are the correct numbers for the symbols they have used, the equation is incorrect so it does not gain any credit here.

11 Part of an electrical circuit is shown.



In 60 seconds, 4.80×10^{20} electrons pass point Z.

(a) Show that the current at Z is about 1.3 A.

(3)

$I = Q/t$ $\Delta Q = e \times 1.60 \times 10^{-19}$

$4.80 \times 10^{20} \times 1.60 \times 10^{-19}$

$= 76.8\,C$

$76.8/60 = 1.28$ Amps

≈ 1.3 Amps.

(b) In 60 seconds, the resistor transfers 24 J of energy.

Calculate the potential difference across the resistor.

(2)

$V = W/Q$

$= 24/\cancel{1.28}\ 76.8$

$= 0.3125\,V$ $0.31\,V$

Potential difference = 0.31 V

ResultsPlus Examiner Comments

(a) This candidate has done two separate calculations to achieve a fully-correct answer for all 3 marks. The calculation for charge is nice and clear, showing both a numerical value and units of coulombs. It is worth noting that if the units had been incorrectly quoted (e.g. farads), we would not penalise this as it is an interim stage in the calculation.
(b) A correct calculation for potential difference with units, scoring full marks on this part too.

Question 12

This is a question relating to the core practical to determine the e.m.f. and internal resistance of a cell. Part (a) is similar to other occasions when this type of graph interpretation has been inspected. Although candidates are usually quite good at interpreting the graph, the common mistake is not to include units on the values of e.m.f. and internal resistance on the answer lines. In both cases this was needed for part (a) on this paper. In spite of this, the most common score achieved on this part of the question was 3 marks.

Part (b) was a more descriptive question, asking the effect on the graph if a second identical cell was added in series. This proved more problematic for students, as most did not follow the instruction to describe the change to the graph, and focused on the changes to the values of e.m.f. and internal resistance. Less than 15% of candidates correspondingly scored both marks on this part.

(a) Determine the e.m.f. ε of the cell, and the internal resistance r of the cell.

(3)

$\varepsilon - Ir = V$

$\varepsilon =$ y-intercept $= 1.5\ V$

$-r =$ gradient $= \dfrac{1.2 - 0.4}{0.4 - 1.46} = -0.7547...$

$0.75\ \Omega$

$\varepsilon =$ 1.5 V

$r =$ 0.75 Ω

(b) The student placed an identical cell in series with the original cell in the circuit. He connected the voltmeter across both cells and repeated the investigation.

The student plotted a new graph of these voltmeter and ammeter readings.

Describe how the new graph is different from the graph for one cell.

(2)

The y-intercept is double the value it was before (3 V). The gradient is now steeper as it is equal to 2r instead of r. The gradient is twice as much as the previous graph.

ResultsPlus
Examiner Comments

A rare response, scoring full marks on both parts. This candidate has clearly laid out their working to show that the gradient is the negative of the internal resistance, and calculated the gradient clearly to get the correct answer. They have also correctly read off the y-intercept to get the e.m.f. value, and both numerical answers have units given too.
On part (b), although they discuss e.m.f. and internal resistance values, they also clearly state that the gradient would be doubled, and that the gradient would also be twice as steep, to score both marks.

(a) Determine the e.m.f. ε of the cell, and the internal resistance r of the cell.

(3)

r = gradient ÷ 6   ε – y-intercept = 1.5

Gradient = $\frac{y_2 - y_1}{x_2 - x_1}$ $\frac{0.6 - 1.2}{1.2 - 0.4}$ = –0.75

(0.4, 1.2) (1.2, 0.6) $\frac{-r}{-1} = \frac{-0.75}{-1}$

~~0.6~~   r = 0.75

ε = 1.5

r = 0.75

(b) The student placed an identical cell in series with the original cell in the circuit. He connected the voltmeter across both cells and repeated the investigation.

The student plotted a new graph of these voltmeter and ammeter readings.

Describe how the new graph is different from the graph for one cell.

(2)

There would be higher Internal resistance ~~therefore~~ the ~~graph would be steeper~~ (the ~~voltage will be~~ lost volts will increase therefore the graph would be steeper as ~~the gradient~~ .

ResultsPlus
Examiner Comments

On this script, the working for part (a) is all correct, but they have unfortunately neglected to add units for both the e.m.f. and internal resistance values given. As a result, they only score MP2 for the calculation of the gradient.
On part (b), they have mentioned about the graph being steeper, but not twice as steep, so no MP1. Although there is mention of lost volts, there is no mention of either e.m.f. or the y-intercept, so MP2 cannot be awarded either.

ResultsPlus

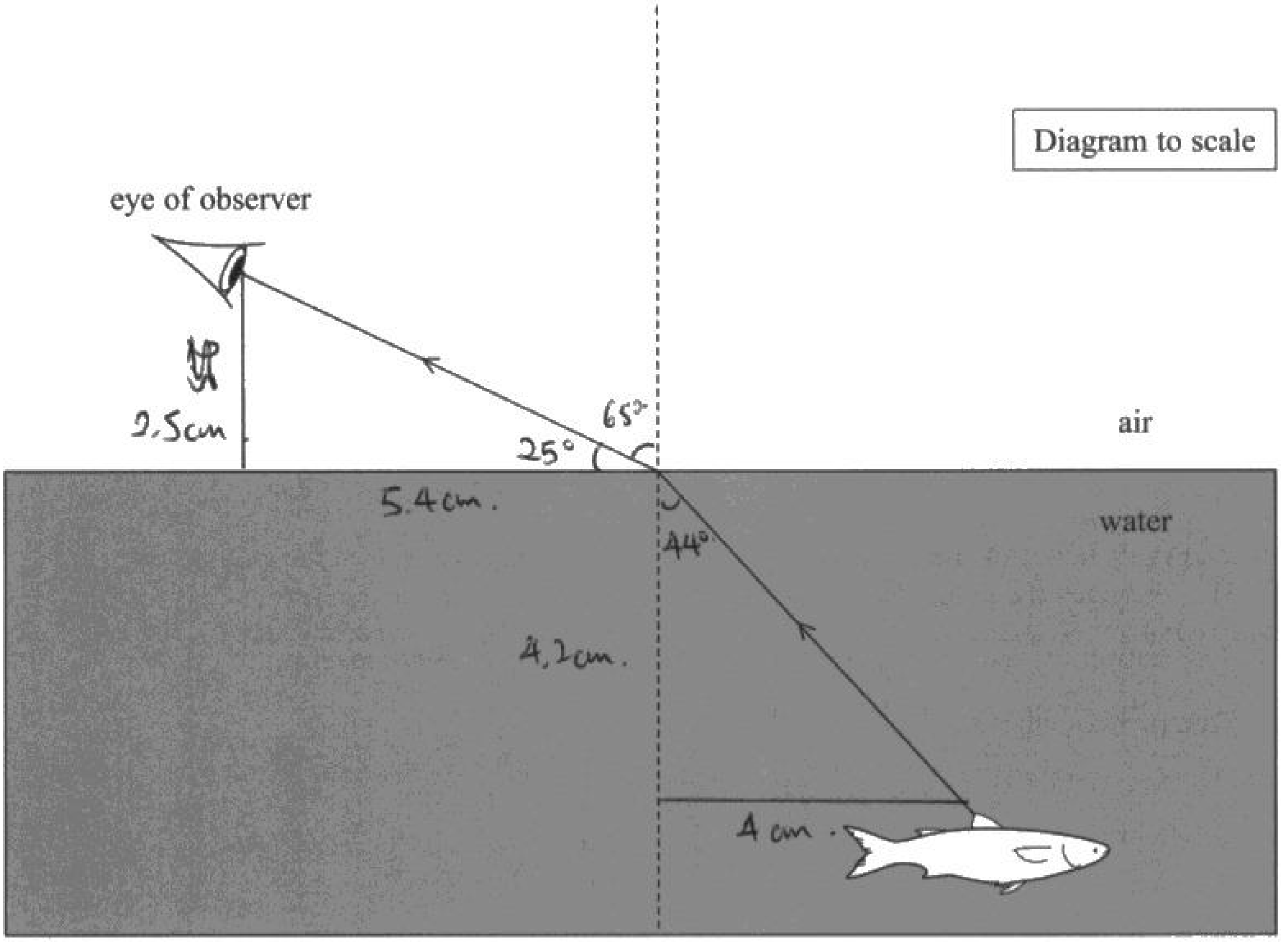
Examiner Tip

When calculating the gradient of a graph, it is best to use as large a triangle as possible. Even with large triangles, it is possible to get a gradient value that is slightly off the main answer given in the mark scheme. Hence the reason for ranges being given for MP1 and MP3.

Question 13 (a)

This question required candidates to measure the angles of incidence and refraction from the diagram given, and to use these values to calculate the refractive index of the water. Although the normal line was drawn on the diagram, a number of candidates measured the angles to the boundary between the water and the air, rather than to the normal line. This could still score MP2 but neither of the other two marks. On the whole, the question was answered well, with more than half of the candidates scoring all 3 marks.

13 The diagram shows a ray of light travelling from a fish to an observer. The ray of light refracts at the water-air boundary.



(a) Determine the refractive index of the water.

You should take measurements from the diagram.

(3)

$\sin 65° = n_2 \sin 44°$

$n_2 = \frac{\sin 65°}{\sin 44°} = 1.3$

Refractive index = 1.3

ResultsPlus
Examiner Comments

Although the answer is only shown to 2 significant figures, this is perfectly acceptable on this question. The angles used are both within a degree of the values on the mark scheme, and are used correctly in the calculation to score all 3 marks.

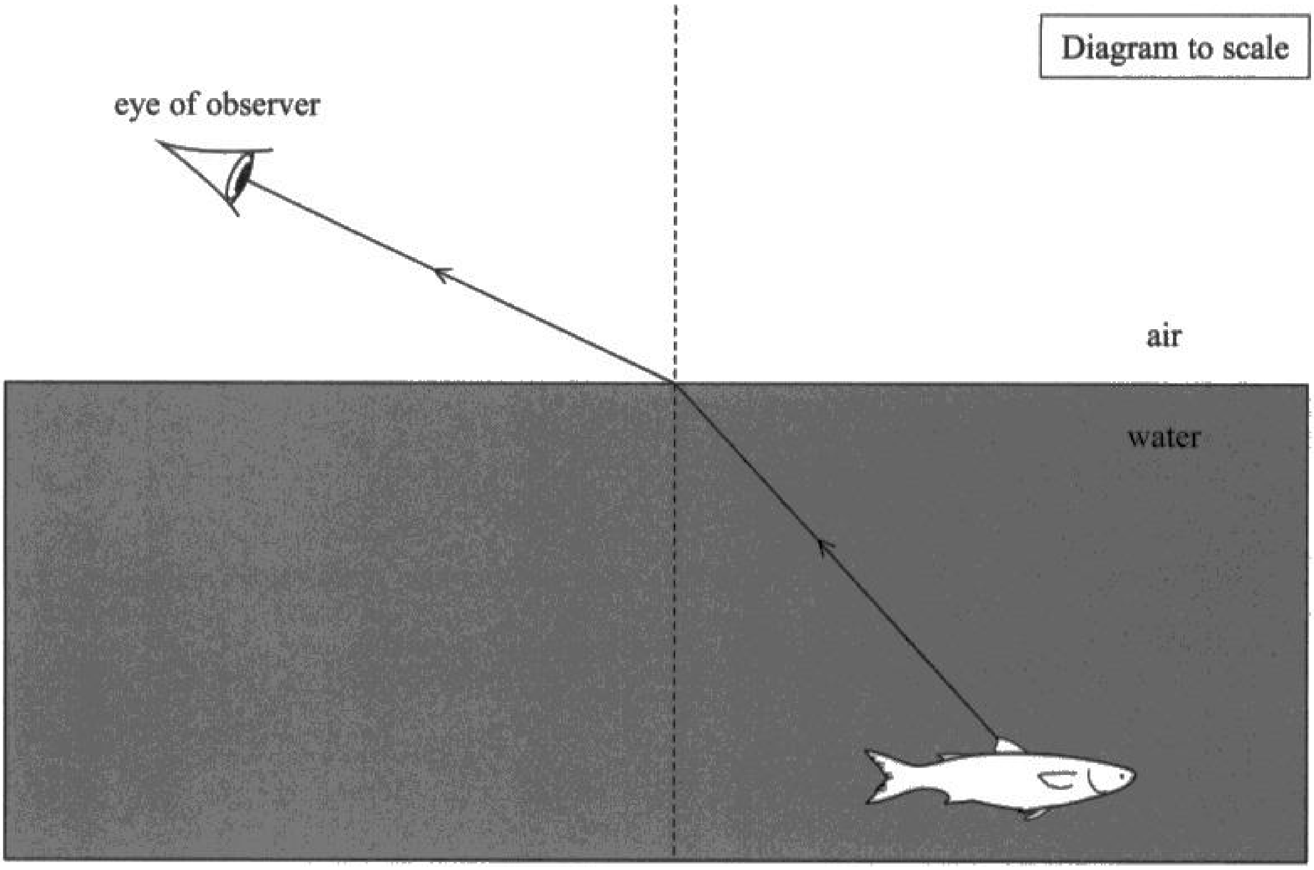
This script is included to show that some students were a little unsure of which measurements needed to be taken from the diagram. This one starts off by drawing out triangles to calculate the angles.

Although it is unclear whether they used these dimensions with trigonometry in order to work out the angles they used, the trigonometry method to find the angles is perfectly acceptable (albeit a little more time-consuming), and many candidates scored all 3 marks by calculating the angles with this method.

ResultsPlus
Examiner Tip

As the refractive index of air is 1, candidates often neglect to include it in their working. Ideally, the substitution of 1 as one of the refractive index values would be substituted into the equation.

13 The diagram shows a ray of light travelling from a fish to an observer. The ray of light refracts at the water-air boundary.



(a) Determine the refractive index of the water.

You should take measurements from the diagram.

(3)

refractive index $\Rightarrow n_1 \sin\theta_1 = n_2 \sin\theta_2$

$\Rightarrow 1 \sin 64 = n_2 \sin 43$

$\Rightarrow \frac{0.8988}{\sin 43} = \frac{n_2 \sin 43}{\sin 43}$

$n_2 = 1.32$

Refractive index = 1.32

ResultsPlus
Examiner Comments

A good 3 mark answer, with 3 significant figures on the answer. The substitutions are clear, and both angles are within a degree of the values given on the mark scheme.

(a) Determine the refractive index of the water.

You should take measurements from the diagram.

(3)

$\theta_i = 25°$ $\theta_r = 46°$

$n_1 \sin\theta_i = n_2 \sin\theta_r$

$\frac{1 \times \sin 25}{\sin 46} = \frac{n_2 \times \cancel{\sin 46}}{\cancel{\sin 46}}$ $n_2 = 0.58$

Refractive index = 0.58

ResultsPlus
Examiner Comments

An example of a candidate measuring the angles between the rays and the boundary between the air and water, rather than to the normal line. Some candidates measured these angles, then subtracted them from 90 degrees, which is perfectly acceptable. However, this one uses both of the measured angles in the equation, which results in them only achieving MP2. The angles (MP1) and answer (MP3) are incorrect, so just 1 mark scored.

Question 13 (b)(i)

This is a standard definition which has appeared on this unit paper on more than one occasion. Unfortunately, the two alternatives given on the mark scheme cannot be mixed and matched, so when candidates describe vibrations/oscillations in relation to planes, they can only score MP3 if they state "including the direction of wave travel". Likewise, if candidates describe vibrations/oscillations in relation to directions, they can only score MP3 if they state "perpendicular to the direction of wave travel".

It is vital that the word "oscillations" or "vibrations" appear in the answers, otherwise candidates will not score any marks.

(i) Explain the difference between unpolarised and plane polarised light.

(3)

unpolarised light is the light vibrate in all the direction. perpendicular to the direction of travel of light.
polarised light is the light vibrate in one direction and perpendicular to the direction of travel of light.

ResultsPlus
Examiner Comments

A good, clear 3 mark response via the second version on the mark scheme. We accepted "travel of light" for "wave travel".

(i) Explain the difference between unpolarised and plane polarised light.

(3)

unpolarised light travels in all directions while polarised light travels in one direction only which is perpendicular to the direction of motion of wave.

ResultsPlus
Examiner Comments

Failure to mention either vibrations or oscillations results in no marks being scored.

Question 13 (b)(ii)

Candidates tend to find questions about polarising filters quite tricky, and this question was no exception. A significant majority of candidates scored 0 or 1 mark, often due to a failure to apply their understanding to this question. Candidates had been asked to explain how a polarising filter could be used to reduce the intensity of the reflected light, in order to be able to see the fish in the water. Unfortunately, a number of candidates simply described a method with two polarising filters that would block all light from passing through.

(ii) Reducing the intensity of the reflected light would help the observer see the fish.

Explain how the observer can use a polarising filter to reduce the intensity of the reflected light.

(2)

Place filter infront of eye and
Rotate polarising filter until intensity of reflacted light reaches a minimum.

ResultsPlus
Examiner Comments

A typical 1 mark response. They have clearly got the idea of rotating the polarising filter, which scores MP1. However, more detail was needed in order to obtain MP2, and this candidate does not consider alignment of planes, or the idea of absorption of light.

(ii) Reducing the intensity of the reflected light would help the observer see the fish.

Explain how the observer can use a polarising filter to reduce the intensity of the reflected light.

(2)

he should look at the filter to see the fish beneath water. rotate the filter so that it is perpendicular to the plane of oscillation of polarized light, so it gets blocked, so there is less reflected light seen.

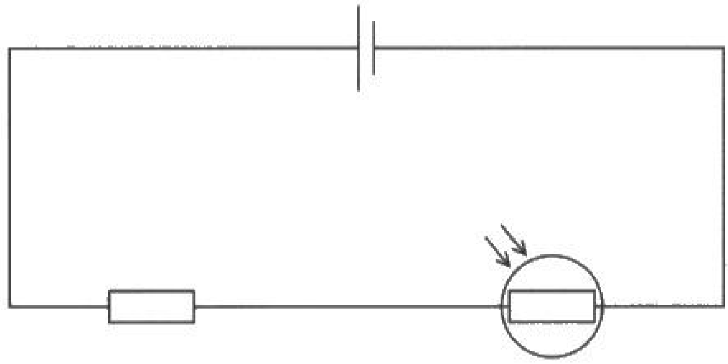
ResultsPlus
Examiner Comments

A really good response, clearly scoring both marking points.

Question 14

This is the question where candidates are expected to create a structured answer showing a coherent and logical sequence in order to answer the question posed. For this series, the question related to a Light Dependent Resistor (LDR) in a circuit. Candidates were expected to explain how LDRs operate and the effect that a higher light intensity would have on the power dissipated by the whole circuit. Unfortunately, a number of candidates failed to answer in terms of the whole circuit and just assessed the changes to the power of the LDR, which generally resulted in them being unable to access the later marks on the mark scheme. In spite of this, more candidates than in previous series managed to achieve the full 6 marks on this question.

***14** The circuit shown contains a fixed resistor and a light dependent resistor (LDR).



Explain why the power dissipated by the whole circuit changes as the intensity of the light incident on the LDR increases.

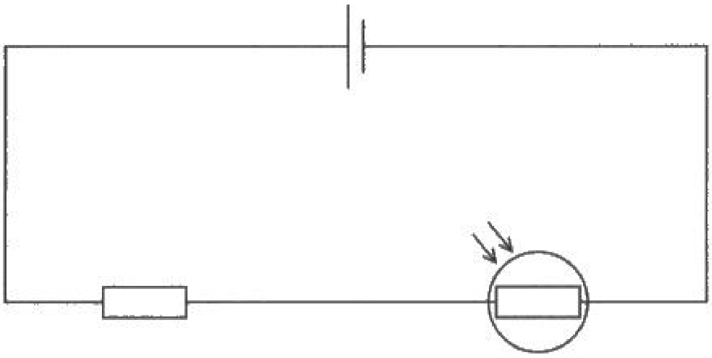
You should refer to why the resistance of an LDR changes as light intensity increases.

$I = P/A$, so intensity and power are directly proportional, if the intensity increases, the power dissipated also increases.
This happens because when the light intensity increases, the number of conduction electrons increases as well, ~~resulting in~~ ~~decrease of~~ which means current is increased, resulting in decrease of resistance as $\frac{V}{I} = R$. Relating to $P = \frac{V^2}{R}$, as resistance is now reduced, the value for power increases.

ResultsPlus
Examiner Comments

The whole answer from this candidate is presumed to be in terms of the LDR rather than the whole circuit. Although they start by considering the intensity equation (which is not really linked to this question), they then go on to say that when the light intensity increases, the number of conduction electrons increases as well. This scores IC2. They then go on to say that the current is increased (IC3) and the resistance decreases (IC1). However, although there is a subsequent equation for power shown, this is clearly not discussed in terms of the whole circuit, so IC4,5 and 6 are all not awarded.
3 IC points equates to 2 Physics marks, and we felt that the linkage was good enough to score the 1 linkage mark available, so it scored 3 marks overall.

*14 The circuit shown contains a fixed resistor and a light dependent resistor (LDR). ↑



$V = IR\downarrow$

$R\downarrow, V\downarrow, I\uparrow$

$P = IV$ same

$\downarrow$

∴ power↓

Explain why the power dissipated by the whole circuit changes as the intensity of the light incident on the LDR increases.

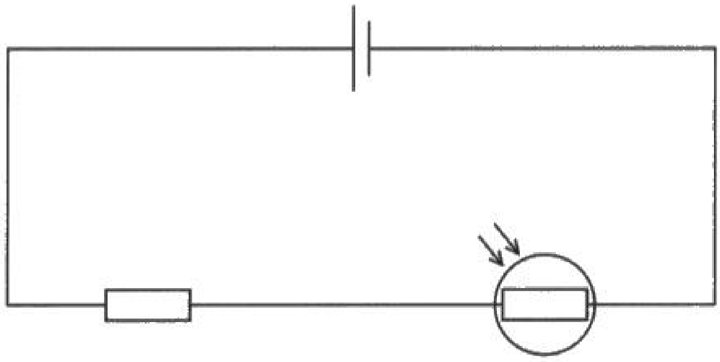
You should refer to why the resistance of an LDR changes as light intensity increases.

As intensity quight of LDR increases, the resistance decreases as V=IR, so means current increases as due to the increase in ~~temper~~ intensity there are more conduction electrons so less resistance as more electrons flow through the circuit & increase the current, the voltage also decreases which increases the voltage across fixed resistor. But overall, the resistance of the circuit decreases ~~while the~~ therefore the current in the circuit increases and as P=IV, and the voltage always remains same throughout the circuit, the power dissipated increases (I is inversly proportional to R)

ResultsPlus
Examiner Comments

A really good answer scoring all 6 marks. At the start this candidate discussed the LDR alone, scoring all of the first 3 IC marks in the first 5 lines.
They then go on to discuss the whole circuit, clearly stating that in terms of P = IV, the whole circuit current increases, whilst the whole circuit voltage (accepted for e.m.f.) remains the same. Relating this to greater power output means that this answer taken together also scores IC4,5 and 6.
There are all 6 IC points, relating to 4 physics marks. We also felt that it was easily clear enough to score the 2 linkage marks to give a total of 6 marks.

*14 The circuit shown contains a fixed resistor and a light dependent resistor (LDR).



Explain why the power dissipated by the whole circuit changes as the intensity of the light incident on the LDR increases.

You should refer to why the resistance of an LDR changes as light intensity increases.

as the intensity of light increase, the resistance of the LDR decrease, so the total resistance of the circuit decrease, ~~the~~ by $I = \frac{U}{R}$, the U of the total circuit is ~~be~~ constant, so the current will increase, $P = UI$, so the power dissipated by the whole circuit will increase

ResultsPlus
Examiner Comments

This rather concise answer scores 5 of the IC points. The only one not seen is IC2 (increase in number of conduction electrons). So it scores 3 physics marks, and 2 linkage to give 5 marks in total.

ResultsPlus
Examiner Tip

Occasionally we see alternative symbols used by candidates. In this response the candidate appears to use the letter U instead of V to represent potential difference. We felt that it was quite clear that they were considering this as potential difference, particularly as it was included in two of the specification equations in their answer. However, it is good practice to stick to the letters and symbols used in the specification when discussing or writing equations as part of an answer.

Question 15 (a)

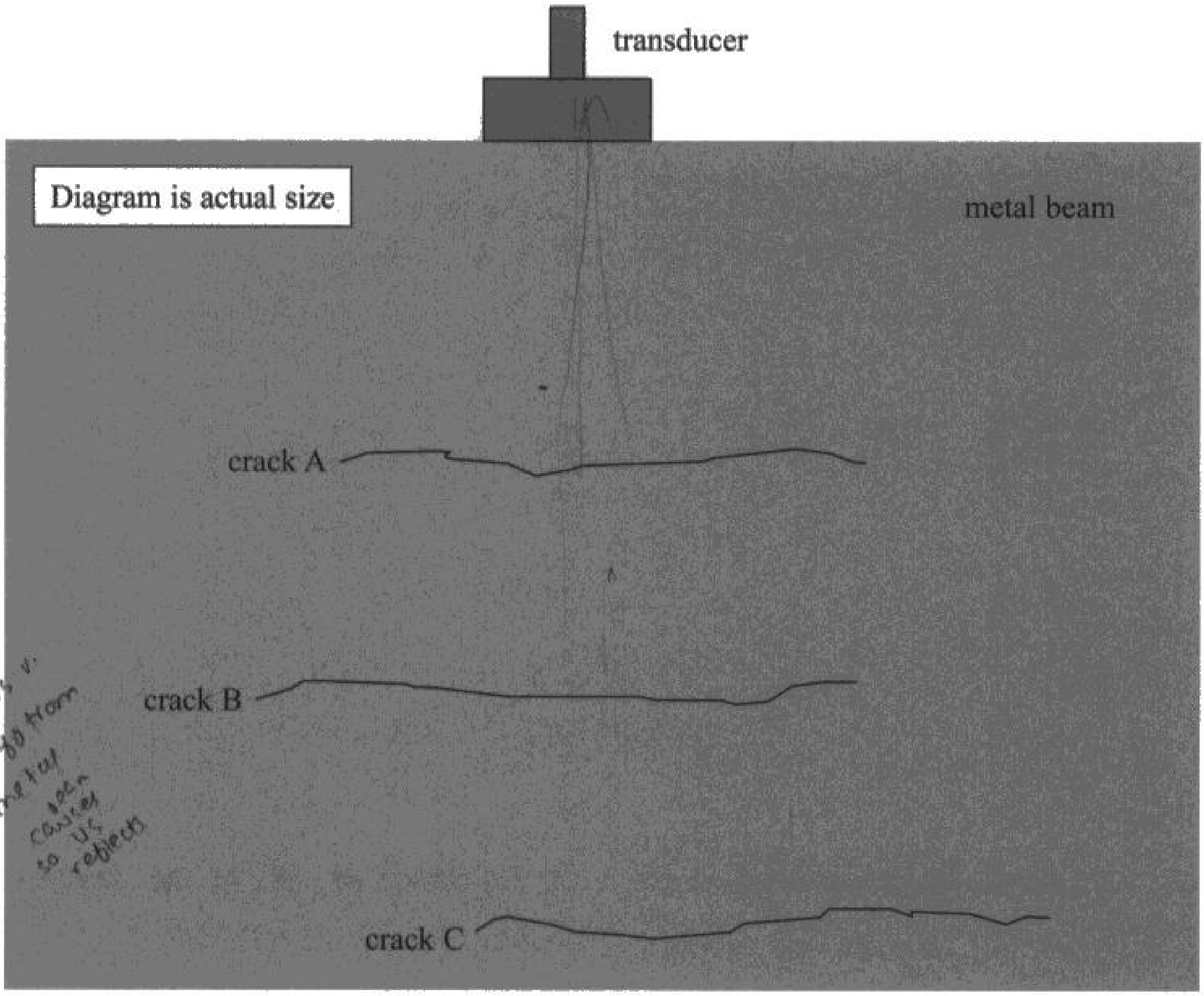
This type of question (in a different scenario) has come up on previous series of this unit. However, this one needed to be related to the example used, so there were a range of different scores on this question. Although it was rare to see all 3 marks achieved, the three separate marking points were commonly seen in answers (just not all in the same answer usually).

Quite a lot of candidates who failed to score MP1 either suggested that the reason for the pulses reaching crack B was due to diffraction around the edge of crack A or that as crack B was longer on the diagram, it could reach it by avoiding crack A altogether. Any such suggestion that avoided the possibility of some of the ultrasound actually passing through crack A usually failed to score MP1.

15 Ultrasound can be used to check for cracks in metal beams.

A transducer emits a pulse of ultrasound into a metal beam. The same transducer detects the returning pulses.

Part of a metal beam is shown. The beam contains three cracks, A, B and C.



D of B is v. diff from metal which causes US to reflect

The transducer detects a returning pulse from each crack.

(a) Explain why there is a returning pulse from crack B.

(3)

Because some ultra sound reflected from crack A depending on the density difference b/w crack A and metal beam. The rest of the ultrasound is transmitted to crack B. The ultrasound is reflected due to the difference in density of crack B and metal B. As it reflects back, so returning pulse from there is detected.

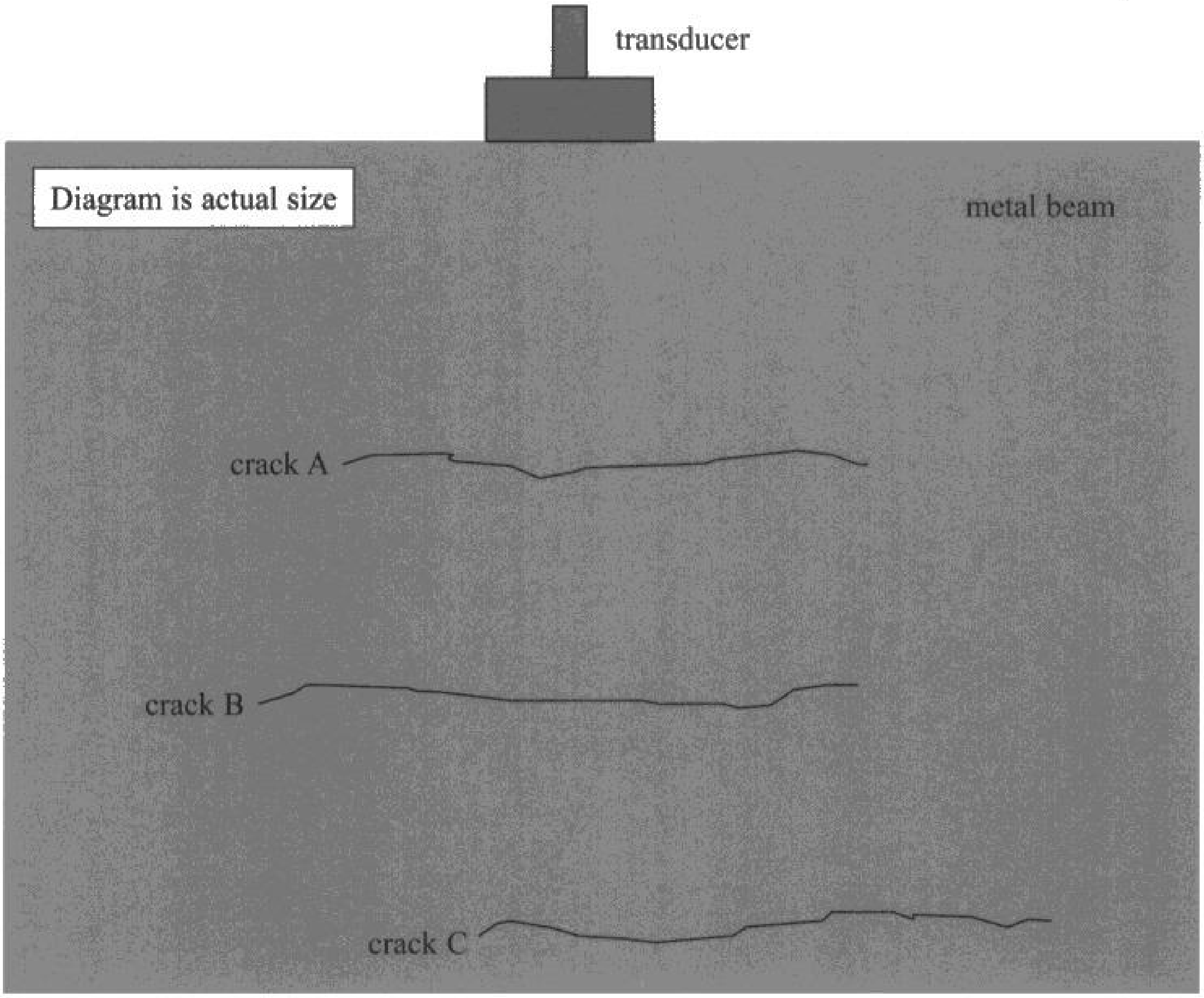
ResultsPlus
Examiner Comments

Although candidates are not informed in the question that the cracks contain air, many assumed this. However, this candidate is not penalised for failing to mention the material in the crack, as they have identified that whatever it is, it has a different density to the metal. MP2 could be achieved by discussing reflection from any of the cracks, so this candidate scores this in their first line by discussing reflection from crack A. Importantly, they then state that the rest of the ultrasound is transmitted further to crack B, so this scores MP1. The discussion of reflection being due to a difference in density scores MP3 so this is a rare example of someone scoring all 3 marks.

15 Ultrasound can be used to check for cracks in metal beams.

A transducer emits a pulse of ultrasound into a metal beam. The same transducer detects the returning pulses.

Part of a metal beam is shown. The beam contains three cracks, A, B and C.



The transducer detects a returning pulse from each crack.

(a) Explain why there is a returning pulse from crack B.

(3)

Pulse returns from crack B due to change in density which can be used to identify the location of the crack by using ~~spe~~ distance = $\frac{\text{speed} \times \text{time}}{2}$ in which speed is known.

ResultsPlus
Examiner Comments

This scores MP3 for the suggestion that the pulse returns from crack B due to a change in density. However, they have not called this a reflection, so there is no MP2. Transmission through crack A is not discussed at all, so no MP1. So just 1 mark in total.

15 Ultrasound can be used to check for cracks in metal beams.

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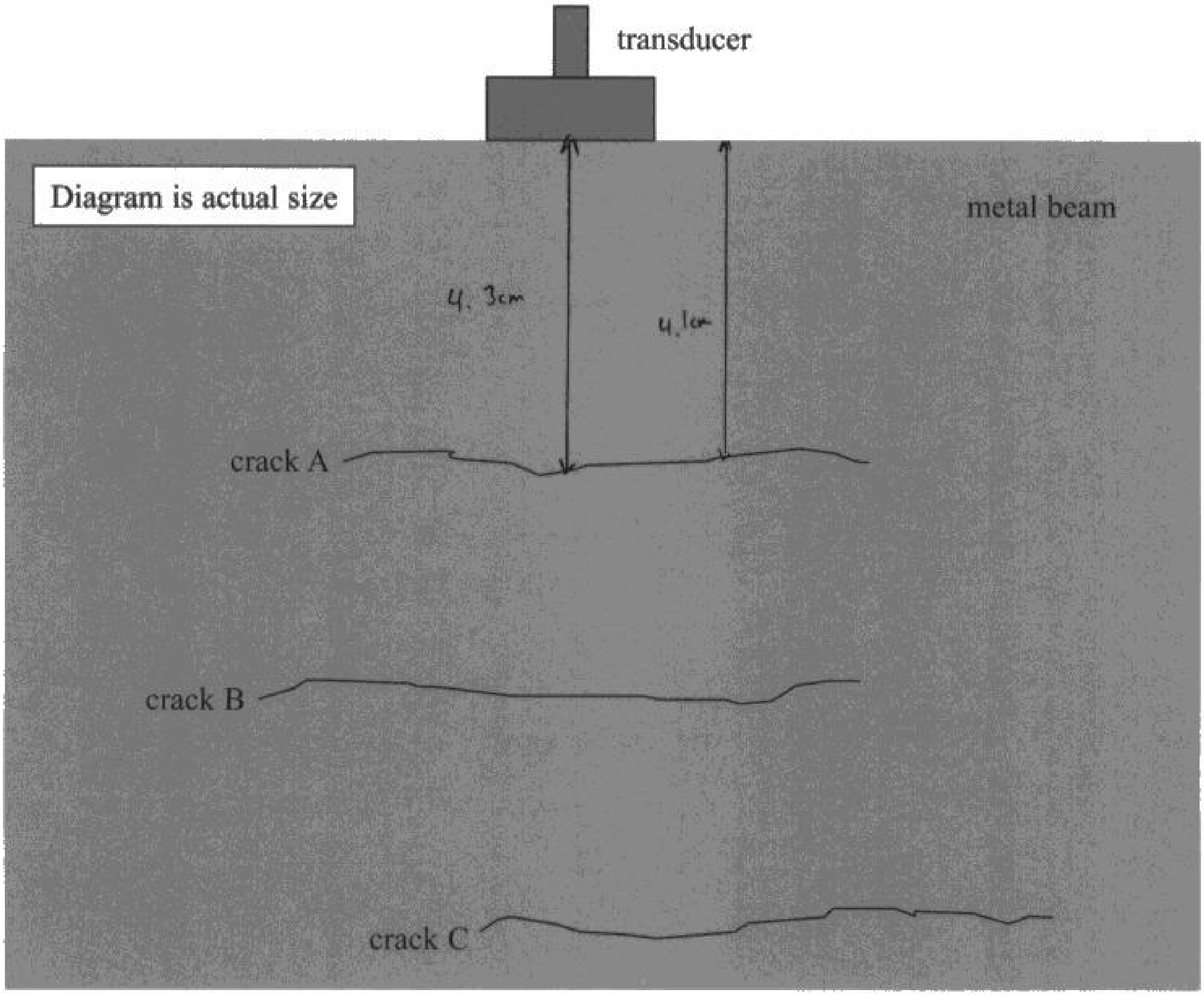


The transducer detects a returning pulse from each crack.

(a) Explain why there is a returning pulse from crack B.

(3)

Emitted pulse reflects on the surface of the crack due to the change in density thus does not pass through but instead reflects to be received by the transducer.

ResultsPlus
Examiner Comments

This candidate scores both MP2 and MP3, even though they never discuss which crack they are considering. They indicate that the wave does not pass through the cracks at all, so does not score MP1.

Question 15 (b)

Although candidates have often been asked to calculate distances from ultrasound pulses being reflected from surfaces (on this unit), the expectation was that they would measure the distance to the cracks on the diagram to compare with their calculated value. This was achieved by some (not all), but it was pleasing to see that more than 60% of the responses scored full marks on this question part.

(b) One pulse returns 1.4×10^{-5} s after being emitted by the transducer.

Deduce whether the pulse has returned from crack A, crack B or crack C.

You should take measurements from the diagram.

speed of ultrasound in metal = $5900\,\mathrm{m\,s^{-1}}$

(3)

$\cancel{1.4 \times 10^{-5}}$

distance traveled by pulse $= 1.4 \times 10^{-5} \times 5900$

$= \cancel{8.56 \times 10^{-2}}\ 8.26 \times 10^{-2}$

distance of crack $= \cancel{7.56}\ 8.26 \times 10^{-2} \div 2$

$= \cancel{0.0378}\ 0.0413$ m

$= \cancel{3.78\text{cm}} = 4.13$ cm

Therefore pulse is returned from crack

ResultsPlus Examiner Comments

This candidate scores MP1 and MP2 only. They start off with a calculation using the full time (there and back) to calculate a distance that they divide by 2 to get the correct value of 4.13cm. Unfortunately, however, they do not conclude which crack this has reflected from so do not score MP3.

ResultsPlus Examiner Tip

The command word "deduce" requires a decision to be made at the end, otherwise full marks cannot be achieved.

(b) One pulse returns 1.4×10^{-5} s after being emitted by the transducer.

Deduce whether the pulse has returned from crack A, crack B or crack C.

You should take measurements from the diagram.

speed of ultrasound in metal = 5900 m s^{-1}

(3)

$V = 5900$, $t = 1.4 \times 10^{-5}$

$s = vt = 5900 \times 1.4 \times 10^{-5}$

$= 0.0826$ m.

$= 8.26$ cm

The pulse has returned from crack B.

ResultsPlus
Examiner Comments

A typical 1 mark response from a candidate who has failed to incorporate the factor of 2 into their calculation, which results in an incorrect distance of 8.26cm, which is most likely to be related to one of the other cracks, so only scores MP1.

(b) One pulse returns 1.4×10^{-5} s after being emitted by the transducer.

Deduce whether the pulse has returned from crack A, crack B or crack C.

You should take measurements from the diagram.

speed of ultrasound in metal = $5900\,m\,s^{-1}$

(3)

7.5cm 1m = 100 = 75

$s = \frac{d}{t}$

$T = \frac{d}{s}$

Crack A	Crack B	Crack C
~~5900 =~~ distance = 7.5cm = 0.75	distance = 8.5 = 0.085	distance = 8.5cm = 0.075
$= \frac{0.75}{5900}$	$= \frac{0.085}{5900}$	$\frac{0.075}{5900}$
$= 1.3 \times 10^{-5}$	1.44×10^{-5}	$= 1.3 \times 10^{-5}$

The returned ~~plus~~ pulse is from crack B as it's $\boxed{1.44 \times 10^{-5}}$

ResultsPlus
Examiner Comments

Some candidates, such as this one, performed a reverse argument to work back from the distances on the diagram and establish which crack would produce the closest time to the one given in the question. This is considered to be an appropriate method to use, although this candidate has failed to apply the factor of 2 so does not score anything apart from MP1.

If the factor of 2 had been included, a reverse argument would still require candidates to compare their calculated time (or speed) with the values given in the question, to demonstrate which one was closest to the true value.

(b) One pulse returns 1.4×10^{-5} s after being emitted by the transducer.

Deduce whether the pulse has returned from crack A, crack B or crack C.

You should take measurements from the diagram.

speed of ultrasound in metal = 5900 m s^{-1}

(3)

$1.4 \times 10^{-5} \times 5900 = 0.0826$ m

$0.0826 \div 2 = 0.0413$ m $= 4.13$ cm

distance between ~~crack~~ crack A and transducer is 4.3cm

the pulse has returned from crack A

ResultsPlus
Examiner Comments

A nice, clear 3 mark response with a conclusion at the end. We did not need to see the distance they had measured, it was just necessary to conclude that it was crack A.

Question 15 (c)

A question testing out the relationship between frequency, wavelength and the level of detail possible in ultrasound imaging. More than half of the candidates failed to score any marks on this, although quite a few who achieved MP1 also then went on to score MP2. Most of the incorrect answers focused on higher frequency being related to higher energy, so the ultrasound could penetrate further into the material. This often appeared to be confused with photon energy, which some candidates went into great detail about.
Another common aspect of confusion was that if the ultrasound was in kHZ but was less than 20kHz, it would no longer actually be ultrasound.

(c) Explain why ultrasound used to detect cracks in metal beams usually has frequencies of MHz, rather than kHz.

(2)

As frequency increases, as velocity is constant. wavelength decreases. Increasing the resolution allowing to detect the cracks in detail.

ResultsPlus
Examiner Comments

A nice, clear 2 mark response.

(c) Explain why ultrasound used to detect cracks in metal beams usually has frequencies of MHz, rather than kHz.

(2)

A higher frequency of ~~a wave~~ ultrasound means its wavelength is shorter as $v = \lambda f$, where ~~f~~ v is constant. This can improve the accuracy of the time measured.

ResultsPlus
Examiner Comments

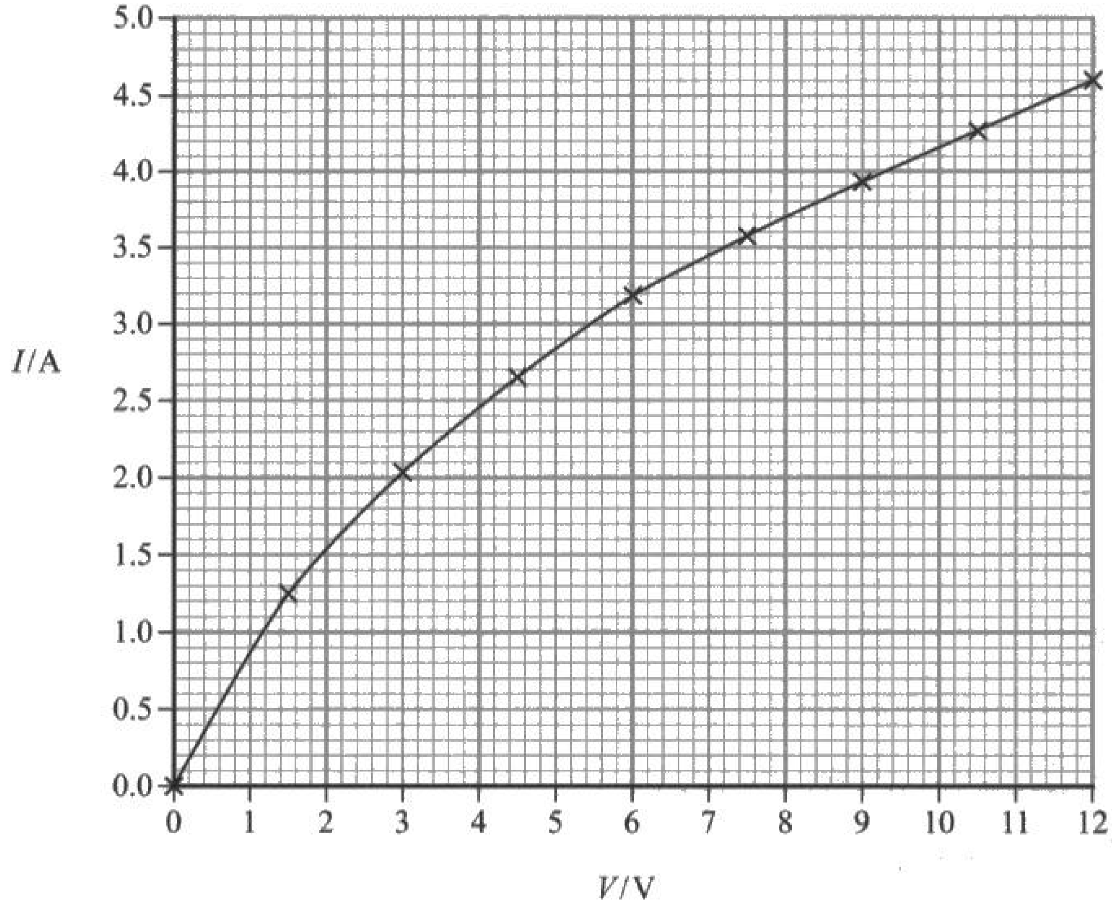
Scores MP1 for shorter wavelength, but not a clear enough statement for MP2.

Question 16 (a)

This question proved to be more difficult for candidates than had been expected. Although more than a third scored all 3 marks, there were also more than a third scoring no marks. The key was to use the graph to establish which combination of potential difference and current from the line of best fit would achieve a total power (P=IV) to exceed 35W. Although this could be considered to be a trial-and-error style question, a quick look at the graph could establish that the lower potential difference readings (when multiplied by the corresponding current) would not achieve 35W. There was no expectation to see any working for this trial-and-error method, so some candidates scored all 3 marks with the briefest of working shown.

16 Drivers use car headlights to emit light in dark conditions.

The graph shows how current I varies with potential difference V for a car headlight.



The headlight will emit light when it dissipates at least 35 W of power.

(a) Determine the minimum potential difference for which the headlight will emit light.

(3)

~~PH~~ 35W power ~~p~~ means that 35J of energy per second is needed

~~to be~~ $35 = VI$ ∴ ~~VI~~ minimum potential different

means the ~~V~~ lowest value ~~of~~ ~~$V = \frac{35}{I}$~~ V such that $V = \frac{35}{I}$

if $V=10$, $10 = \frac{35}{I}$, $I = 3.5$ if $V = 6$ $6 = \frac{35}{I}$ $I \approx 5.83$

if $V=8$, $8 = \frac{35}{I}$, $I = 4.375$ if $V=9$, $9 = \frac{35}{I}$ $I \approx 3.89$

If $V = 8.8$, $\frac{35}{8.8} = I$

≈ 3.98

Minimum potential difference = 9 V

Mi

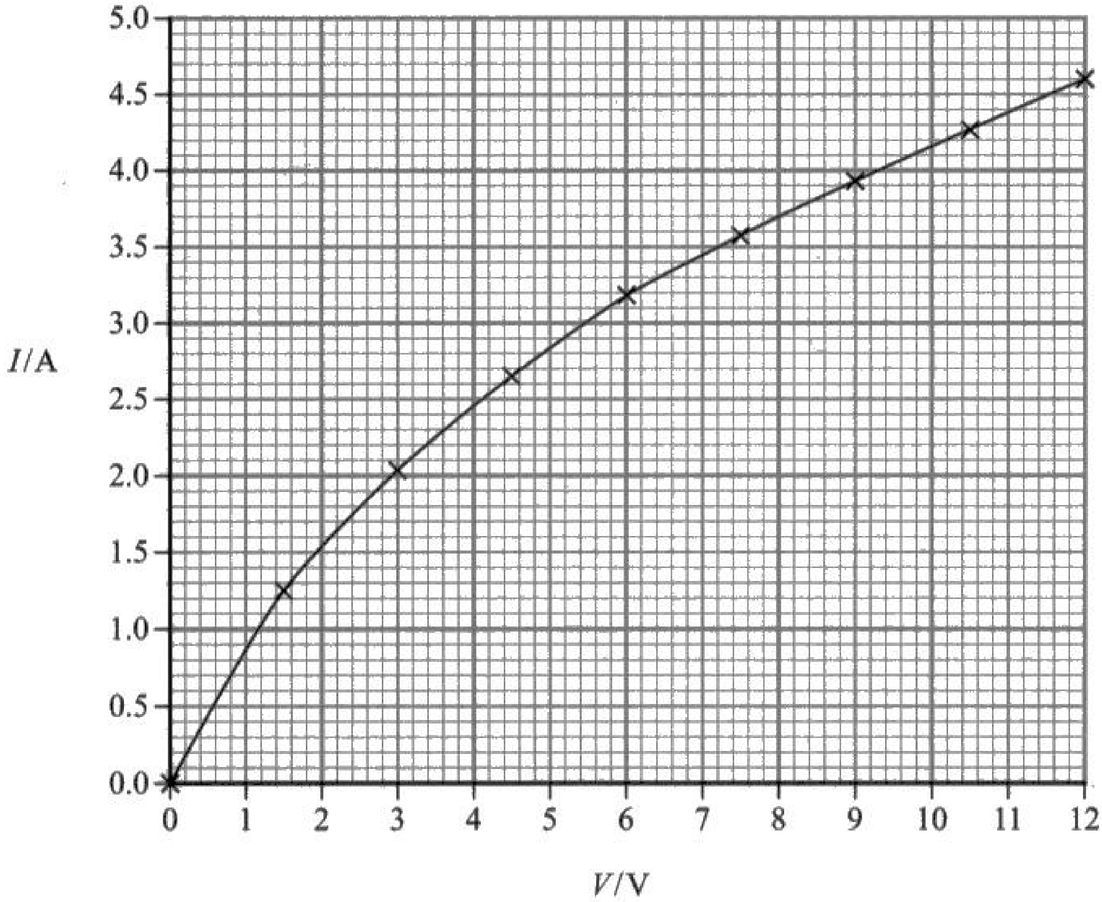
Minimum potential difference = 9V ~~accur~~ (0.2 V accuracy)

ResultsPlus
Examiner Comments

This candidate uses a lot of trial and error throughout their answer and thankfully came to the correct conclusion that 9V is the correct value. Bear in mind that this is a rare occasion when we accept a 1 significant figure answer, considering that the value is difficult to exactly determine, and is very close (although slightly below) 9V.

16 Drivers use car headlights to emit light in dark conditions.

The graph shows how current I varies with potential difference V for a car headlight.



The headlight will emit light when it dissipates at least 35 W of power.

(a) Determine the minimum potential difference for which the headlight will emit light.

(3)

$P = VI$

$V = \frac{35}{4.6} = 7.61$ V

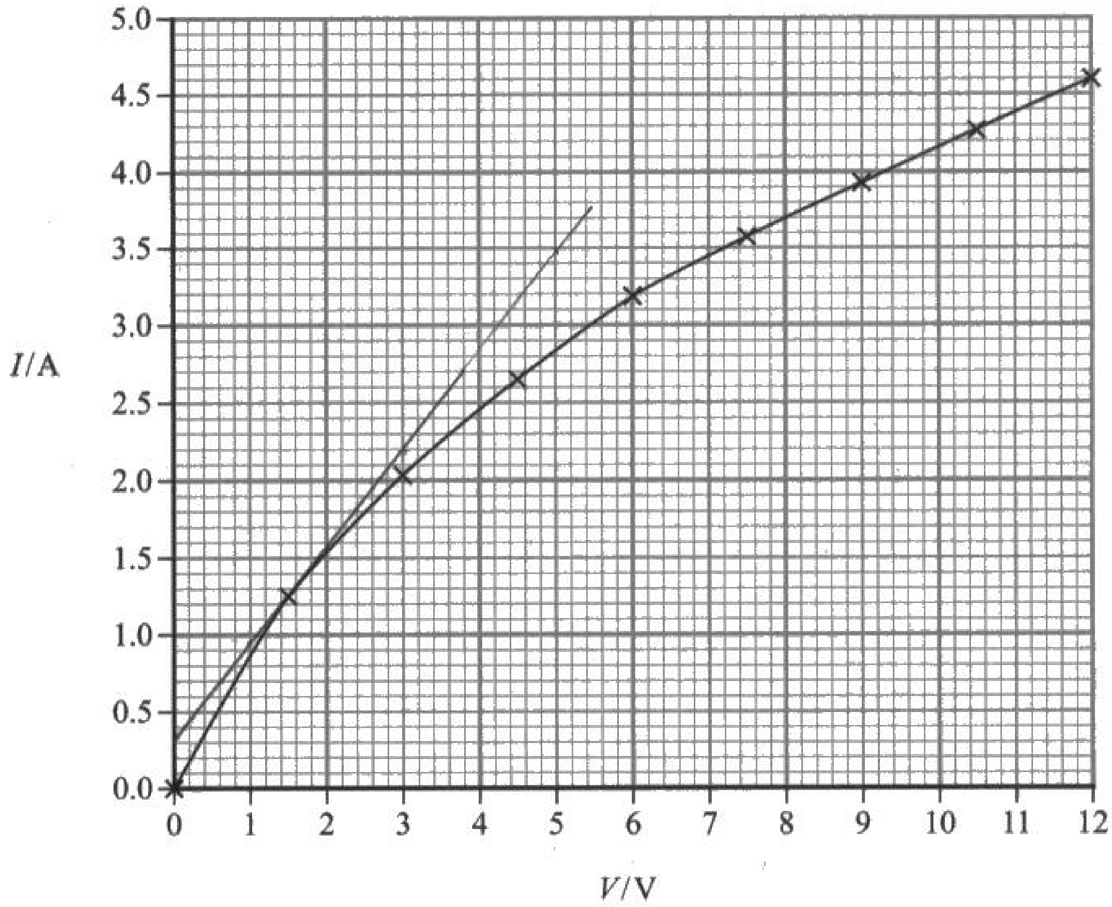
Minimum potential difference = 7.61 V

ResultsPlus
Examiner Comments

A typical 1 mark response, where the candidate has assumed that the working current should be the highest value shown on the graph, which is around 4.6A. They then use this with the power equation to establish a potential difference of 7.6V.
On the best fit line, a current of 4.6A does not correspond to a potential difference of 7.6V so this cannot score MP1. However, it scores MP2 as they have used the power equation with 35W and a value of current from the graph. The answer is incorrect, so no MP3.

16 Drivers use car headlights to emit light in dark conditions.

The graph shows how current I varies with potential difference V for a car headlight.



The headlight will emit light when it dissipates at least 35 W of power.

(a) Determine the minimum potential difference for which the headlight will emit light.

(3)

$(5, 3.5)$ = $\frac{2.2 - 3.5}{3 - 5}$ = $\frac{1.3}{2}$ = 0.65 = R

$(3, 2.2)$

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

$35 \times 0.65 = V^2 = 22.75 = 4.769$

Minimum potential difference = 4.8 V

ResultsPlus
Examiner Comments

A common wrong answer, where the candidate has calculated a gradient of the graph at a particular point (the point to draw this tangent seemed to vary from candidate to candidate, and it was not sure from many of these answers why that point was chosen).
As a consequence, we never see corresponding values from the best fit line being used in P=IV, so no marks are achieved here.

Question 16 (b)(i)

This question required candidates to consider the advantages of connecting headlights in parallel with a battery as opposed to being in series. This was not well answered, and suggests that candidates find it difficult to apply the rules for series and parallel circuits to examples given.

Some points made in candidate answers were correct, but were either not relevant to the answer or not clear enough to score any credit. For example, many candidates discussed the fact that headlights in parallel would have a lower total resistance than headlights in series – unfortunately this does not constitute any major advantage for the parallel arrangement.

There were also many answers focusing on the fact that the p.d. across each headlight in parallel would be the same. Without any further discussion, this could not score any credit as the p.d. across each headlight in series would also be the same. The key thing was that the p.d. across the headlights in parallel would be the full 12V, whereas in series it would just be 6V each.

There were also lots of candidates who appeared to think that in series all of the p.d. would be used up by one headlight, leaving hardly any for the other one.

One final answer which did not get credit was once again something that is true, just not relevant to this answer. Quite a few answers spoke of the fact that each headlight could be turned on and off independently with different switches. This is not really a key advantage of connecting headlights in parallel as they are intended to both switch on at the same time.

(b) In a car, two headlights are connected in parallel with a 12.0 V battery. The battery has negligible internal resistance.

(i) Explain the advantages of connecting the headlights in parallel with the battery rather than in series.

(3)

Both headlights will have same voltage in parallel. But in series, one headlight will have higher voltage than the other one, so one headlight may not function well.

ResultsPlus Examiner Comments

Quite a common answer scoring 0 marks. Although both headlights do have the same voltage in parallel, the key is to tell us that they have the full battery voltage.

(b) In a car, two headlights are connected in parallel with a 12.0 V battery. The battery has negligible internal resistance.

(i) Explain the advantages of connecting the headlights in parallel with the battery rather than in series.

(3)

~~A~~ Both headlights get 12V rather than voltage splitting, when they are connected in parallel intensity of light is higher and if one headlight breaks the other doesn't stop working.

The combined resistance of headlights is lower in parallel, so higher current.

ResultsPlus
Examiner Comments

A nice, clear answer scoring all 3 marking points.

Question 16 (b)(ii)

This was always intended to be a demanding questions, and indeed the candidates found this very difficult to achieve full marks. The key issue was that once candidates had worked out the resistance of one of the headlights when they were in parallel, the assumption was often made that the resistance would still be the same when they were in series, which is not the case. As a consequence, many candidates ended up scoring 2 marks as they concluded that the statement was correct.

(ii) A student writes the following statement.

When connected to the 12.0V battery, the combined resistance of two headlights in parallel is one quarter of the combined resistance of two headlights in series.

Deduce whether the student is correct.

Your answer should include calculations using data from the graph.

(3)

In parallel: $4.6\,I$ at $12V$, $I_t = 9.2$, $R_t = \frac{V}{I} = \frac{12}{9.2} \approx 1.30\,\Omega$

In series: 6V each, $I = 3.15$, $R_t = \frac{V}{I} \approx 3.81\,\Omega$

$\frac{3.81}{1.3} \approx 2.93 \neq 4$, ∴ student is incorrect

ResultsPlus
Examiner Comments

One of a number of alternative methods whereby all 3 marks could be achieved. Initially it appears that this candidate cannot score all 3 marks as there is no evidence of the resistors in parallel formula being used. However, they have realised that if each headlight is in parallel, the total circuit current will be double the current for each lamp individually, so do a resistance calculation based on the combined current, leading to a correct parallel resistance of 1.30 Ohms.
They then do a similar calculation for the headlights in series to establish a combined resistance of 3.8 Ohms (although we do not see 12V being used in the calculation for this, we can assume it from their description of 6V each).
The comparison at the end shows that the ratio of series resistance to parallel resistance is actually less than 4, so it scores all 3 marks.

(ii) A student writes the following statement.

When connected to the 12.0V battery, the combined resistance of two headlights in parallel is one quarter of the combined resistance of two headlights in series.

Deduce whether the student is correct.

Your answer should include calculations using data from the graph.

(3)

According to graph

[redacted] parallel $V_1 = 12V$ $I_1 = 4.6A$, $R = \frac{V_1}{I_1} = 2.609\,\Omega$

Series $V_2 = 6V$ $I_2 = 3.2A$, $R_2 = \frac{V_2}{I_2} = 1.875\,\Omega$

Total R for [redacted] parallel $= \frac{1}{\frac{1}{2.609} + \frac{1}{2.609}} = 1.305\,\Omega$

Total R for series $= 1.875\,\Omega + 1.875\,\Omega = 3.75\,\Omega$

$\frac{3.75\Omega}{4} = 0.938\,\Omega \neq 1.305$ not correct

ResultsPlus
Examiner Comments

Another good alternative to score all 3 marks. This time we can see the resistors in parallel formula used for MP2, and all of the rest of the working is there. This time they divide their series resistance by 4 to show that it does not equal the parallel resistance they have calculated, and this is a good way of answering the question.

(ii) A student writes the following statement.

When connected to the 12.0V battery, the combined resistance of two headlights in parallel is one quarter of the combined resistance of two headlights in series.

Deduce whether the student is correct.

Your answer should include calculations using data from the graph.

(3)

$V = I \times R \qquad V = 12V \quad I = 4.6A$

$R = \frac{V}{I} = \frac{12}{4.6} = 2.609\,\Omega.$

Series

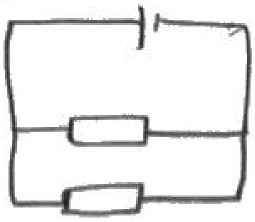
$R_T = R_1 + R_2 = 2 \times 2.609 = 5.217$

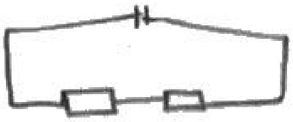
parallel

$1/R_T = 1/R_1 + 1/R_2 = 1/2.609 + 1/2.609 = 0.7667.$

$R_T = 1.304.$

$\frac{5.217}{4} = 1.304.$ Hence the student is correct.





ResultsPlus
Examiner Comments

Around one third of all candidates came up with this sort of response, scoring MP1 and MP2 only. They have assumed that the resistance of headlights is the same, regardless of potential difference across them, so have calculated a total parallel resistance of 1.3 Ohms, which is exactly one quarter of their calculated series resistance, so they conclude that the statement is correct. This does not score MP3.

Question 16 (c)

A drift velocity calculation with a slight twist. Rather than giving a value for cross-sectional area, candidates needed to calculate it from the resistivity equation using the data given. The fact that a key piece of data provided was the resistance per unit length of the copper wire was a factor that increased the difficulty of the question. This, along with the need for candidates to substitute the charge of an electron into the drift velocity equation, were the two biggest issues in terms of candidates being able to achieve full marks. In spite of this, almost half of the candidates scored full marks on this part.

Although no examples are included here, some candidates decided to use the resistance of one of the headlights (from the previous part of the question) to work out the cross sectional area of the wire. Considering that the value given in the question was resistance per unit length, they often ended up getting the correct value for area even though the resistance value used was completely unrelated to this question. This was ignored when marking, as candidates could use any created value of resistance to do the same calculation to work out cross sectional area. They still had to use the resistivity equation which is where MP1 was awarded.

(c) The headlights are connected in the circuit using copper wire. The current in the wire is 4.60 A.

Calculate the drift velocity of electrons in the copper wire.

number of charge carriers per m^3 of copper = $8.49 \times 10^{28}\,m^{-3}$
resistivity of copper = $1.72 \times 10^{-8}\,\Omega m$
resistance per unit length of the copper wire = $1.75 \times 10^{-2}\,\Omega m^{-1}$

(3)

$I = 4.6$

$I = nAq\cancel{v}v$

$4.6 = 8.49\times10^{28} \times 9.83\times10^{-7} \times 1.6\times10^{-19} \times v$

$v = 0.54\,ms^{-1}$

$R = \frac{\rho l}{A} = \cancel{1.72\times10^{-8}} \times$

$\rho = \frac{RA}{l}$

$A = \frac{1.72\times10^{-8}}{1.75\times10^{-2}}$

$= 9.83\times10^{-7}$

Drift velocity = $0.54\,ms^{-1}$

ResultsPlus
Examiner Comments

This candidate has calculated cross sectional area correctly, so scores MP1. They then substitute this value into the drift velocity equation (with all of the other terms also correctly substituted) so score MP2. They have clearly made a calculator error after that point, as the answer is incorrect (so no MP3).

(c) The headlights are connected in the circuit using copper wire. The current in the wire is 4.60 A.

Calculate the drift velocity of electrons in the copper wire.

number of charge carriers per m^3 of copper = $8.49 \times 10^{28} m^{-3}$
resistivity of copper = $1.72 \times 10^{-8} \Omega m$
resistance per unit length of the copper wire = $1.75 \times 10^{-2} \Omega m^{-1}$

(3)

$I = Vq n A$

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

$1.75 \times 10^{-2} = \frac{1.72 \times 10^{-8} \times 1}{A}$

$A = 9.829 \times 10^{-7}$

$4.6 = v \times 9.829 \times 10^{-7} \times 8.49 \times 10^{28} \times 4.6$

$1.198 \times 10^{-23} ms^{-1}$

$1.2 \times 10^{-23} ms^{-1}$

Drift velocity = $1.2 \times 10^{-23} ms^{-1}$

ResultsPlus
Examiner Comments

This candidate has calculated the area correctly so scores MP1. However, they have not correctly substituted the charge of an electron into the drift velocity equation (they have used the current instead), so cannot score MP2 (nor MP3).

(c) The headlights are connected in the circuit using copper wire. The current in the wire is 4.60 A.

Calculate the drift velocity of electrons in the copper wire.

number of charge carriers per m^3 of copper = $8.49 \times 10^{28}\,m^{-3}$
resistivity of copper = $1.72 \times 10^{-8}\,\Omega m$
resistance per unit length of the copper wire = $1.75 \times 10^{-2}\,\Omega m^{-1}$

1

(3)

$I = nqvA$

$4.6 = 8.49 \times 10^{28} \times 1.6 \times 10^{-19} \times v \times 9.828 \times 10^{-7}$

$4.6 = 13351.13\,v$

$v = 3.445 \times 10^{-4}$

$= 3.44 \times 10^{-4}$

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

$1.75 \times 10^{-2} = \frac{1.72 \times 10^{-8} \times 1}{A}$

$R = \rho \frac{l}{A}$ $\qquad A = 9.828 \times 10^{-7}$

$RA = \rho l$

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

Drift velocity = 3.4×10^{-4}

ResultsPlus
Examiner Comments

The first two marks are clearly scored here. However, there are no units on the correct numerical answer, so no MP3.

(c) The headlights are connected in the circuit using copper wire. The current in the wire is 4.60 A.

Calculate the drift velocity of electrons in the copper wire.

number of charge carriers per m^3 of copper = $8.49 \times 10^{28}\,m^{-3}$
resistivity of copper = $1.72 \times 10^{-8}\,\Omega m$
resistance per unit length of the copper wire = $1.75 \times 10^{-2}\,\Omega m^{-1}$

(3)

$I = nqvA$

$R = \frac{\rho l}{A}$ $RA = \rho l$

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

$1.75 \times 10^{-2} = \frac{1.72 \times 10^{-8}}{A}$

$A = 9.83 \times 10^{-7}$

$4.6 = 8.49 \times 10^{28} \times 1.6 \times 10^{-19} \times v \times 9.83 \times 10^{-7}$

$4.6 = 13353.072 v$

$v = 3.4 \times 10^{-4}\,ms^{-1}$

Drift velocity = $3.4 \times 10^{-4}\,ms^{-1}$

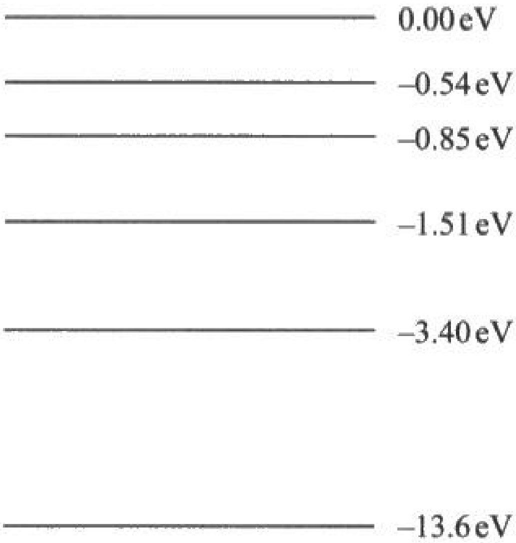
ResultsPlus
Examiner Comments

A fully correct, 3 mark response.

Question 17 (a)

A standard description for which almost half of the candidates scored full marks. The main reason for a failure to achieve these marks was the common confusion between this scenario and the photoelectric effect.

17 The diagram shows the energy levels for an atom of hydrogen.



An electron is in the −13.6 eV (ground state) level of this atom.

(a) A photon interacts with this electron.

Explain why this interaction causes the emission of another photon.

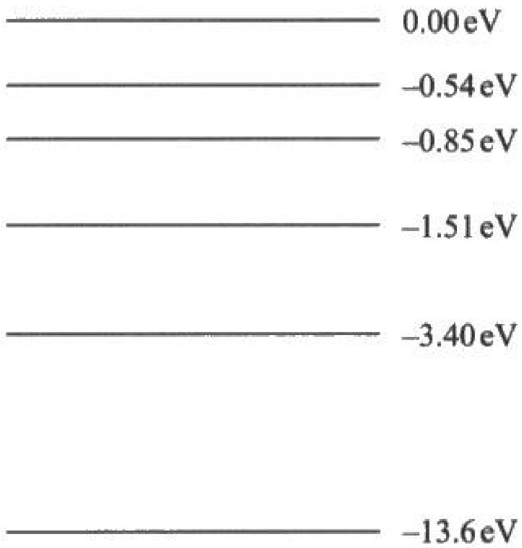
(2)

Photon 1 transfers energy to electron, electron gets excited ~~any~~ and goes to a higher eV level ~~it~~ then transfers energy to the Photon 2, therefore emission of Photon 2 takes place.

ResultsPlus
Examiner Comments

Scores MP1 for electron moving to a higher energy level. However, no mention of it dropping back down, so no MP2.

17 The diagram shows the energy levels for an atom of hydrogen.



An electron is in the −13.6 eV (ground state) level of this atom.

(a) A photon interacts with this electron.

Explain why this interaction causes the emission of another photon.

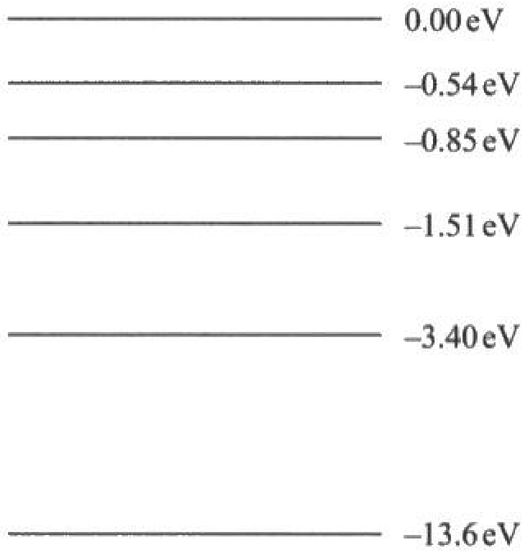
(2)

The photon transfers all its energy to the electron, so electron it gains energy and move to higher energy level and then fall back to lower energy level by emitting energy in the ~~form o~~ form of photons

ResultsPlus
Examiner Comments

A nice, clear 2 mark response.

17 The diagram shows the energy levels for an atom of hydrogen.



An electron is in the −13.6 eV (ground state) level of this atom.

(a) A photon interacts with this electron.

Explain why this interaction causes the emission of another photon.

(2)

The energy of a photon will be ~~absorbed~~ transfer to the electron once they are absorbed, and it will immediately emit another photon as the ~~tran~~ emission of photoelectrons is ~~a~~ immediate and do not have any time ~~to~~ delay.

ResultsPlus
Examiner Comments

An answer with a common confusion that this question is related to the photoelectric effect. Sometimes it is difficult for candidates to establish that photons and photoelectrons are different particles, so they are interchanged within answers.

Question 17 (b)(i-ii)

There are two linked parts to this question. Part (i) was a relatively straightforward calculation, similar to many that have appeared on this unit previously. As such, it was unsurprising that more than half of the candidates scored all 4 marks. Part (ii) was marked with part (i) as the answer to (i) would potentially have some bearing on how candidates answered part (ii). However, for any aspect of error carried forward to be applied in (ii), it had to be related to photon release i.e. a drop in energy levels.
Unfortunately, many candidates stating that this photon could not be released made an argument in terms of the jump from ground state to the next highest level being greater than the energy they had calculated in (i). Unfortunately, such arguments were irrelevant to this question, as candidates were meant to consider energy jumps **downwards**, rather than upwards.

(b) A photon has a wavelength of 218 nm.

(i) Determine the energy, in eV, of this photon.

(4)

$f = \frac{c}{\lambda} = \frac{3.00 \times 10^8}{218 \times 10^{-9}} = 1.376 \times 10^{15}$ Hz

$E = hf = 6.63 \times 10^{-34} \times 1.376 \times 10^{15} = 9.124 \times 10^{-19}$ J

$(9.124 \times 10^{-19}) \div (1.6 \times 10^{-19}) = 5.702$ eV

Photon energy = 5.70 eV

(ii) Explain whether the atom of hydrogen could emit a photon with this energy.

(2)

A hydrogen atom can't emit a photon with is energy because none of the differences between any of its energy levels is equal to 5.70 eV. Since the energy levels are discrete, the difference must be 5.70 eV.

ResultsPlus
Examiner Comments

A really nice, clear answer scoring full marks on both sections. The calculation in (i) is done step-by-step and the answer is correct. In part (ii) they state that there is no difference between energy levels that is equivalent to this value, then state that the energy levels are discrete, so score both marks.

(b) A photon has a wavelength of 218 nm.

(i) Determine the energy, in eV, of this photon.

(4)

$E = hf$

$E = 6.63 \times 10^{-34} \times \dfrac{(3.00 \times 10^{8})}{(218 \times 10^{-9})} = 9.1239 \times 10^{-19}\ \text{J}$

$=$ J to eV

$\cancel{E = 1.3761 \times 10^{-17} (\times 1.60 \times 10^{-19})}$

$\cancel{E = 0.0220\ \text{eV}}$

$9.1239 \times 10^{-19} \times (1.60 \times 10^{-19})$

$= 1.4598 \times 10^{-37}$

$\to 1.46 \times 10^{-37}$

Photon energy = ~~[illegible]~~ eV

(ii) Explain whether the atom of hydrogen could emit a photon with this energy.

(2)

yes

~~No~~ because Hydrogen atom has discrette energy levels and the photon energy ~~is above~~ is ~~more~~ within the energy levels and is above the grand state energy

ResultsPlus
Examiner Comments

In part (i) of this response, the candidate has correctly achieved an answer for photon energy in Joules by combining together the equations for MP1 and MP2. However, they then multiply rather than divide by e, so do not score MP3 and MP4.

Although their answer to (i) is incorrect, they score MP1 on part (ii) for stating that the energy levels are discrete. Although it might seem a little unusual, they could have also gained MP2 if they had said that their value from (i) did not correspond to any of the differences of energy level shown (however, they have not done this, so MP2 is not achieved here).

(b) A photon has a wavelength of 218 nm.

(i) Determine the energy, in eV, of this photon.

(4)

~~$E = hf = 218 \times 10^{-9} \times 6.63 \times 10^{-34} = 1.45 \times 10^{-40}$ J~~

~~$1.45 \times 10^{-40} \div (1.6 \times 10^{-19}) = 9.0 \times 10^{-22}$ eV~~

$f = \frac{v}{\lambda} = \frac{3 \times 10^{8}}{218 \times 10^{-9}} = 1.38 \times 10^{15}$

$E = hf = 1.38 \times 10^{15} \times 6.63 \times 10^{-34} = 9.12 \times 10^{-19}$ J

$9.12 \times 10^{-19} \div (1.6 \times 10^{-19}) = 5.7$ eV

Photon energy = ~~9.0×10^{-22}~~ 5.7 eV

(ii) Explain whether the atom of hydrogen could emit a photon with this energy.

(2)

- The atom of hydrogen could not emit a photon with this energy.
- As there is no difference ~~of~~ between energy levels which has exactly the value of 5.7 ev.

ResultsPlus
Examiner Comments

A fully correct answer (with full working) for all 4 marks on part (i). On part (ii) they pick up MP2 at the end but there is no evidence of MP1, so just 1 mark here.

ResultsPlus
Examiner Tip

Although this candidate has rightly crossed out their initial working on part (i) as it was incorrect, it is worth noting that if a candidate crosses through their answer, and does not replace it, examiners will look for any marking points in the crossed out section and give credit where marks are seen. The moment a candidate replaces crossed out work with something else (as this candidate does), we ignore any crossed out work.

Question 17 (c)(i)

A relatively simple calculation using the photoelectric effect equation, with more than half of the candidates achieving full marks. The most common mistake was failing to recognise that v was squared in the equation, so they did not square root to get the answer at the end.

(c) Photons with energy 1.63×10^{-18} J are incident upon the surface of a metal plate. The metal surface releases electrons due to the photoelectric effect.

(i) Calculate the maximum possible speed of the electrons.

work function = 5.89×10^{-19} J

(3)

$hf = \phi + \frac{1}{2}mv^2 \rightarrow 1.63 \times 10^{-18} = 5.89 \times 10^{-19} \times 0.5 \times$
$9.11 \times 10^{-31} \times v^2$

$\sqrt{\frac{1.63 \times 10^{-18}}{2.683 \times 10^{-49}}} = v^2 \rightarrow 2.46 \times 10^{15}$

Maximum possible speed of the electrons = 2.46×10^{15} ms

ResultsPlus
Examiner Comments

This candidate has started off by correctly identifying the equation they need to use to establish the maximum speed of electrons. However, when they substitute the numbers into the calculation, they turn the plus sign in the original equation into a multiplication sign, which will result in them achieving an incorrect answer. Unfortunately, this means that they do not score MP1 as they have not substituted their numbers into a correct equation. However, it is clear to see that they have incorporated the kinetic energy equation, with the correct mass of the electron, so can score MP2. Obviously the answer is incorrect so no MP3, and this scores 1 mark in total.

(c) Photons with energy 1.63×10^{-18} J are incident upon the surface of a metal plate. The metal surface releases electrons due to the photoelectric effect.

(i) Calculate the maximum possible speed of the electrons.

work function = 5.89×10^{-19} J

(3)

$E = \phi + \frac{1}{2}mv_{max}^2$

$1.63 \times 10^{-18} = 5.89 \times 10^{-19} + \frac{1}{2} \times 9.11 \times 10^{-31} v^2$

$v^2 = 2.2854 \times 10^{12}$

$v = 1.5 \times 10^6$ m/s

Maximum possible speed of the electrons = 1.5×10^6 m/s

ResultsPlus
Examiner Comments

A fully correct answer for all 3 marks. All numbers substituted correctly and answer has units.

(c) Photons with energy 1.63×10^{-18} J are incident upon the surface of a metal plate. The metal surface releases electrons due to the photoelectric effect.

(i) Calculate the maximum possible speed of the electrons.

work function = 5.89×10^{-19} J

(3)

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

$1.63 \times 10^{-18} = 5.89 \times 10^{-19} + \frac{1}{2} \times 9.11 \times 10^{-31} \times v^2$

Maximum possible speed of the electrons = 1.51×10^{6}

ResultsPlus
Examiner Comments

A common 2 mark response, where the substitutions and numerical answer are fully correct. However, the units are missing from the answer so this just scores MP1 and MP2 only.

ResultsPlus
Examiner Tip

A candidate who fails to write the units down on any of their calculated answers on this paper could end up failing to achieve 5 marks, if all of their calculated values are correct. 5 marks is commonly the difference of a whole grade on this unit.

(c) Photons with energy 1.63×10^{-18} J are incident upon the surface of a metal plate. The metal surface releases electrons due to the photoelectric effect.

(i) Calculate the maximum possible speed of the electrons.

work function = 5.89×10^{-19} J

(3)

$hf = \phi + \frac{1}{2}mv^2$ $\quad 1.63 \times 10^{-18} = 5.89 \times 10^{-19} + \frac{1}{2}(9.11 \times 10^{-31})v^2$

$4.52 \times 10^{-19} = \frac{1}{2}(9.11 \times 10^{-31})v^2$

$\frac{9.04 \times 10^{-19}}{(9.11 \times 10^{-31})} = v^2$

$v = 996150 \text{ ms}^{-1}$

Maximum possible speed of the electrons = 996150 ms^{-1}

ResultsPlus
Examiner Comments

This candidate has scored both of the first two marking points in their substitutions in the first line of this answer. They fail to score MP3 as their subtraction of the work function from the photon energy has been calculated incorrectly. This prevents MP3 being achieved but the substitution is OK for both of the first two marks. If this candidate had neglected to show full substitutions and started their answer with the second line, they would only have scored MP2 as we would not know where the value of 4.52 came from.

Question 17 (c)(ii)

This is a similar-style question to others over the last couple of years on this unit, although this was much more focussed on the particle model of light, as opposed to the wave model. The mark scheme was split into two sections (observations and explanations) from which a maximum of 2 marks could be scored on each. All of the marking points were seen quite regularly, although some candidates spent too much of their answer just considering the observations rather than the explanations.

In the script descriptions, the 6 separate marking points are referred to as MP1 to MP6, in order, even though of course there are only 3 marks for the question in total.

(ii) Explain why the photoelectric effect demonstrates light behaving as a particle, rather than a wave.

(3)

- there is a minimum amount of energy (work function) therefore, frequency (threshold freq) for electrons to be emitted, so this explains that there is a one to one interaction between photons & electrons, so photons are discrete packets, and 1 electron can only absorb energy from 1 photon. (energy cannot build up gradually).
- also release of electrons is instantaneous, no energy build up (as with waves).
- also increasing intensity only increases no of electrons emitted (not KE as with waves). In order to change KE frequency should be increased.

(Total for Question 17 = 14 marks)

ResultsPlus
Examiner Comments

Although in places the writing is quite tricky to read, this candidate scores 3 marks here (and perhaps 4 of the marking points in total).
In line 1 they state that there is a minimum energy (work function) for electrons to be emitted. This does not score MP5 as they have not stated that the photon energy needs to be greater than this.
However, within this same sentence they state that there is a minimum frequency to release electrons, which allows the award of MP1.
They then state that there is a one to one interaction between photon and electron, scoring MP6.
In the second paragraph, they state that the release of electrons is instantaneous, and this scores them MP2. On the next line, which is not completely clear, they also imply that the intensity does not affect the KE of the released electrons so this could score MP3. However, they have already scored all 3 marks anyway.

(ii) Explain why the photoelectric effect demonstrates light behaving as a particle, rather than a wave.

(3)

Light travels as packets of energy called photons. One photon transfers all of its energy to one electron. The release of ~~the~~ electrons from a metal surface is instantaneous. ~~The~~ photon energy is ~~proportional to the~~ directly proportional to the frequency of light. A minimum amount of energy is ~~needed~~ required by the electron to be ~~em~~ emitted from the metal surface.

(Total for Question 17 = 14 marks)

ResultsPlus
Examiner Comments

Another script scoring 3 marks. This time (in the order they are seen) we are awarding MP6, MP2 and MP4.

(ii) Explain why the photoelectric effect demonstrates light behaving as a particle, rather than a wave.

(3)

the kinetic energy of the electrons that are ejected are dependant upon the frequency of the light and not the intensity which would be the case for wave behavior. Intensity affects the rate of electrons emitted as more photons are emitted towards the metal plate so more electrons are ejected. The ejection of electrons is instantaneous rather than a build up of energy followed by ejection of an electron.

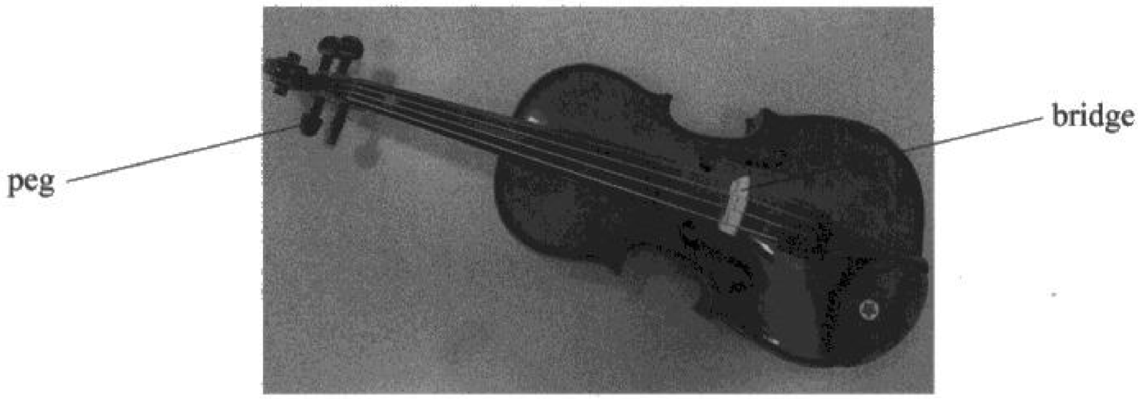
ResultsPlus
Examiner Comments

This script scores MP3 (for KE of released electrons not being related to intensity) and MP2 for the instantaneous release.

Question 18 (a)

There are signs from the responses seen to this question that candidates are getting more familiar with the fact that questions about the formation of stationary waves on this unit have to be related to the application given in the question. In previous series, far too many candidates have given generic descriptions of how a stationary wave forms, without applying it. Knowing that there are two waves travelling in opposite direction, candidates need to be able to explain how the two waves travelling in opposite directions were created in the first place. In this case it was because the wave created when plucking the string went to the end of the string and reflected from the ends. There were almost equal numbers of candidates scoring 0,1,2 and 3 marks on this question, making it quite a good discriminator on the paper.

18 The photograph shows a musical instrument called a violin.



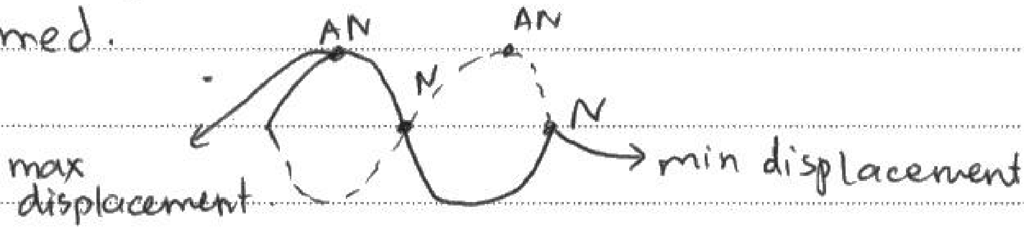
The violin has four strings. Each string is held in a fixed position by a peg and at the bridge.

When a string is plucked, a stationary wave forms on the string.

(a) Explain how a stationary wave forms on the string.

(3)

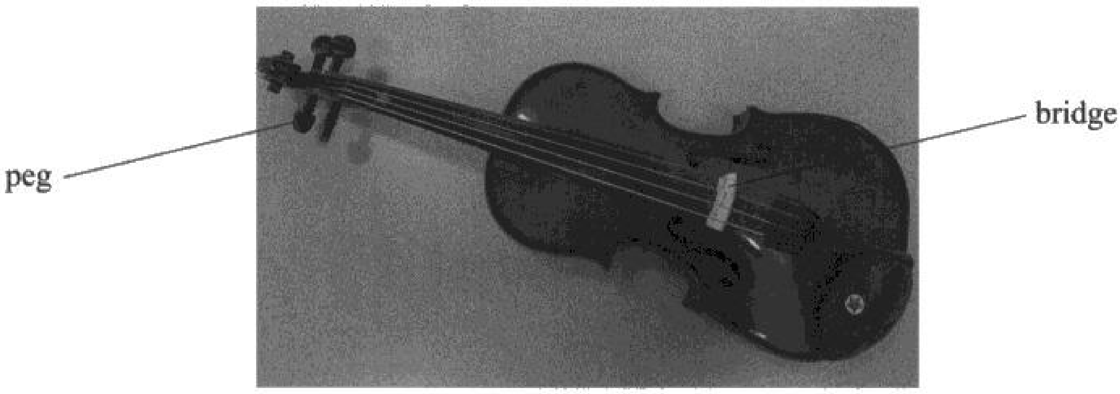
When two progressive waves interfere with eachother travelling in opposite directions, nodes & antinodes are formed.



ResultsPlus
Examiner Comments

A standard stationary wave description which only scores MP3 as the answer has not been applied to this scenario.

18 The photograph shows a musical instrument called a violin.



The violin has four strings. Each string is held in a fixed position by a peg and at the bridge.

When a string is plucked, a stationary wave forms on the string.

(a) Explain how a stationary wave forms on the string.

(3)

When a string is plucked, a wave is formed and it is reflected from the bridge then superposition takes place. A stationary wave is formed when two waves travelling opposite directions superpose. Points of minimum amplitude are called nodes and points of maximum amplitude are called antinodes.

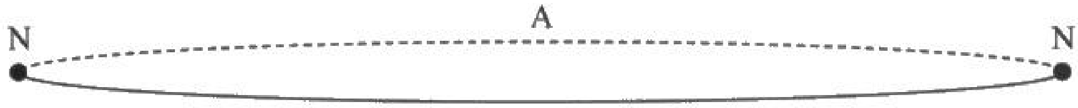
ResultsPlus
Examiner Comments

This candidate scores all 3 marks in the first two lines. They then follow it up with the more generic description, but have already given the application-specific response to score the marks.

Question 18 (b)

A really well answered "deduce" question, where a decision had to be made about which string was being used. More than half of the candidates scored the full 4 marks on this. For those using the correct equations, the most common reason for a failure to score full marks was the failure to recognise that the length of the string would only represent half of the wavelength. Otherwise, this was answered well.

(b) The simplest stationary wave that can be formed on the string has a node (N) at each end and an antinode (A) at the centre, as shown.



The frequency of this wave is called the fundamental frequency.

The strings on a violin have different fundamental frequencies, as shown in the table.

String	Fundamental frequency/Hz
1	196
2	294
3	440
4	659

The tension in one of the strings is 71.5 N. The length of the string is 32 cm and the mass per unit length of the string is $2.03 \times 10^{-3}\,\text{kg m}^{-1}$.

Deduce whether this is string 1, 2, 3 or 4. $\mu =$ ______

(4)

$v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{71.5}{2.03 \times 10^{-3}}} = 187.67$

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

$\frac{187.67}{0.32} = f \times 0.32$

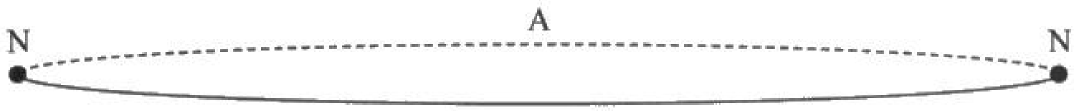
$586.48 = f$

Most likely string 4.

ResultsPlus
Examiner Comments

The most common incorrect answer, although it still scored 2 marks (MP1 and MP2). The wavelength used in the equation for MP2 had to be something related to the value of 32cm, but did not need to be correct for this mark.

(b) The simplest stationary wave that can be formed on the string has a node (N) at each end and an antinode (A) at the centre, as shown.



The frequency of this wave is called the fundamental frequency.

The strings on a violin have different fundamental frequencies, as shown in the table.

String	Fundamental frequency / Hz
1	196
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3	440
4	659

The tension in one of the strings is 71.5 N. The length of the string is 32 cm and the mass per unit length of the string is $2.03 \times 10^{-3}\,\text{kg m}^{-1}$.

Deduce whether this is string 1, 2, 3 or 4.

(4)

$v = \sqrt{\frac{T}{\mu}}$ $\quad v = f\lambda$

$f\lambda = \sqrt{\frac{T}{\mu}}$ $\quad f = \frac{1}{16 \times 10^{-2}}\sqrt{\frac{71.5}{2.03 \times 10^{-3}}}$

$f = \frac{1}{\lambda}\sqrt{\frac{T}{\mu}}$ $\quad = $ [illegible] $\quad$ string 1

$\lambda = \frac{L}{2}$

ResultsPlus
Examiner Comments

Although we never see an answer for the speed of the waves or the frequency, this candidate has correctly combined both of the equations (and substituted numbers) for MP1 and MP2 to be awarded. This candidate has halved the distance given (rather than doubled) and has not converted the wavelength into metres, but neither of these things are penalised in MP1 nor MP2. Indeed, if they had used 64(cm) as their wavelength, without converting to metres, they could still potentially score all of the first 3 marking points.

ResultsPlus
Examiner Tip

Power of 10 errors in most calculation questions are generally only penalised when it comes to the final answer mark. The exception is when the power of 10 error is made on a constant (from the equation sheet) or a value with a power given in the question, where the power of 10 is simply being transferred rather than converted.

(b) The simplest stationary wave that can be formed on the string has a node (N) at each end and an antinode (A) at the centre, as shown.

The frequency of this wave is called the fundamental frequency.

The strings on a violin have different fundamental frequencies, as shown in the table.

String	Fundamental frequency / Hz
1	196
2	294
3	440
4	659

The tension in one of the strings is 71.5 N. The length of the string is 32 cm and the mass per unit length of the string is $2.03 \times 10^{-3}\,\text{kg}\,\text{m}^{-1}$.

Deduce whether this is string 1, 2, 3 or 4.

(4)

$$f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$$

$$= \frac{1}{2 \times 32 \times 10^{-2}}\sqrt{\frac{71.5}{2.03 \times 10^{-3}}}$$

$$= \cancel{1.56\times} \quad 293.2$$

The string is String 2 is the disntiguished string.

ResultsPlus
Examiner Comments

A fully correct answer for 4 marks. The only conclusion required was that it was string 2.

ResultsPlus
Examiner Tip

In some deduction questions, a comparison is needed between the calculated value and the value from the table, but seeing as in this question the answer of 293 Hz is so close to 294 Hz, we decided that this would not be needed on this occasion. So simply an answer of 293 Hz and "String 2" was enough.

Question 18 (c)

The final question on this paper proved to be quite tricky for candidates to score full marks on, as the level of detail required to fully cover all aspects was quite considerable. As a result, half of the candidates ended up scoring either 1 or 2 marks, with the remainder mostly scoring 0.

One of the main reason for failure to achieve some of the marks was the number of occasions that answers were given that contradicted each other. For example, many candidates mentioned that the two waves had different speeds, but then stated that they had the same wavelength, thus failing to achieve MP2. Likewise, quite a few candidates mentioned about having the same frequency but a different time period, making it impossible to award MP1.

The other big issue was candidates mentioning something relating to a marking point, but only doing it for one of the two waves e.g. stating that the waves on the string were transverse, but not then stating that the sound waves were longitudinal.

Undoubtedly, candidates tend to produce answers to fill the given space, and some on this question spent too much of their answer talking about factors that were not relevant to the answer. Even when they did, they were often provided as a back up to something they had already achieved the mark for e.g. after stating that the sound waves were longitudinal and the stationary waves were transverse (picking up MP5), some went on to give the full definition of longitudinal and transverse waves.

Although the scoring was not particularly high on this question, it was pleasing to see that each of the marking points was regularly seen – it was just unfortunate that so many candidates did not score any more than 3 of them in the same answer.

Answers relating to the fact that the sound wave was progressive whilst the stationary wave was stationary were not permitted.

(c) The stationary wave on the string causes sound waves to be transmitted through the air.

Describe the similarities and differences between the stationary wave on the string and the sound waves transmitted through the air.

(5)

Sound waves transmitted thraugh air is Progressive wave. Stationary Store energy while Progressive wave ~~Sound waves~~ sound wave transfer energy. ~~Both Both of them are~~ Sound waves longitudinal while stationary waves are transverse Amplitude of Stationary Varies While that of Sound waves are Same. Frequency or wavelength of Stationary wave ~~Gro~~ are same while that of sound waves are not Same. Besides, there are nodes and antinodes ~~which~~ in Stationary waves while they are absent in sound waves. Stationary waves are superposed while sound waves through air is not. There are Interference pattern and Coherence In Stationary wave while they are absent in sound waves.

ResultsPlus
Examiner Comments

This one scores 3 marks early in their answer (MP4 in lines 2-3, MP5 in line 3, MP3 in lines 4-5). They also seem to be heading towards MP1 on line 5, but then state that the frequency of sound waves is not the same, so they fail to achieve this mark. The rest of the answer contains some details which are correct, but just not relevant to the answer.

(c) The stationary wave on the string causes sound waves to be transmitted through the air.

Describe the similarities and differences between the stationary wave on the string and the sound waves transmitted through the air.

(5)

The stationary wave on the string is transverse while the wave transmitted through ~~the~~ air is longitudinal. The ~~wave~~ sound wave transmitted have the same frequency as the stationary wave, but different wavelength and velocity. The sound waves transmitted are compressional waves, but the stationary wave vibrates string perpendicular to the wave direction.

ResultsPlus Examiner Comments

This one also scores 3 marks, but this time it is MP5, MP1 and MP2 (seen in that order in their answer).

Paper Summary

Overall, the standard of answers displayed on this paper was in line with previous series. However, there were some aspects of the more descriptive questions where the answers needed to be clearer. Calculations are usually performed to a very high standard, although it remains disappointing that so many candidates fail to include units on their answers. Questions relating to core practical tasks were generally answered well although, as in previous series, the multiple choice question 8 perhaps highlighted a lack of understanding of the meaning of some of the terms in the diffraction grating equation.

Most of the contexts within which the questions were asked on this paper were not particularly unusual, but candidates still need to ensure that they apply their understanding to the scenario delivered. In particular, questions such as Q13(b)(ii), Q15(a), Q16(a) and Q18(a) demonstrated this most clearly.

Based on their performance on this paper, candidates are offered the following advice:

- Make sure that the answers to all calculation questions include relevant units.
- Make sure that appropriate scientific language is used in answers. For example, on both Q15(a) and Q18(a), the word "bounced" was used instead of "reflected" on a number of responses. Likewise, descriptions of polarisation, such as those needed for Q13(b)(i) and Q13(b)(ii), needed to be far more technical than the responses seen from a significant number of candidates.
- For calculation questions, always show all of the numbers being substituted into the equations.
- For questions relating to wave-particle duality, it would be advantageous for candidates to spend more time learning the distinction between questions relating to energy levels in atoms, as opposed to questions relating to the photoelectric effect. Ultimately, one of these is where an electron is responsible for emitting a photon and the other is where a photon is responsible for emitting an electron. Too many responses to Q17(a) were about the photoelectric effect and too many responses to Q17(c)(ii) were about energy levels in atoms.