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Examiners' Report
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IAL Physics WPH12 01

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Introduction

This is the first time that the Pearson Edexcel International AS paper WPH12, Waves and Electricity, has been taken by candidates. Section A of the paper is 10 marks of multiple choice questions, and Section B contains 9 longer questions which consist of short open responses, calculations and extended writing.

Although there are some slight changes to the content included in the specification from the WPH02 unit of the previous specification, the assessment for WPH12 is broadly similar. Apart from the slight changes to specification content, there are 3 main changes to the style of the paper in terms of content. Firstly, the Quality of Written Communication (QWC) questions from the previous specification have been replaced with 6 mark linkage questions (Q14 on this paper). The second difference is that the new IAL specification has a new assessment objective AO2b. This allocates around 10 marks of the paper to questions that require candidates to draw a conclusion. An example on this paper is Q11, which requires candidates to do a calculation, followed by a conclusion about which metal has been used. The final difference is that the specification for WPH12 contains 5 Core Practicals which can be assessed by way of questioning on this paper. These Core Practicals are not used in the assessment of paper WPH13.

In general, candidates performed reasonably well on this paper. The main challenges were on questions requiring more application, such as Q17(b)(i). Candidates appeared to be able to complete the paper in the allocated time as most attempted the last question, Q19(c).

The multiple choice questions in Section A were generally answered well, with an average of 6 marks scored out of 10 by the candidates. On Q02, many candidates chose option A which is a standard description of when **two** polarising filters are used, but this question was simply about one polarising filter. For Q03, although candidates realised that the string had a stationary wave on it, many chose that it was longitudinal. For the majority of candidates who got the wrong answer for Q10, the option chosen was A, an answer which would have been correct if the graph was showing a progressive wave.

Question 11

This is the first of the questions testing the new assessment objective AO2b. Although a fairly standard calculation question, there was a need to make a decision at the end about which metal the wire was made from. In order to achieve the last marking point, there needed to be a calculated value and a conclusion that the material was aluminium.

Although most of the candidates answered this question well, there were a number who did not halve the diameter before using it in πr^2 - if candidates did not halve the diameter value given, they ended up getting an answer that was close to the value for iron.

There were a few power of 10 errors and some candidates were confused about which terms in the equation were for resistance and resistivity. However, this was seen far less frequently than in previous series on the previous specification.

Some candidates did reverse calculations to show what the resistance value would be if inserting the three values of resistivity for the listed metals into the formula. Although this did gain credit, it should be reminded that this approach leads to the candidate performing three separate calculations which would lead to less time being available for later questions.

11 A student carried out an experiment to determine the resistivity of a metal in the form of a wire. She made the following measurements:

$$\text{length of wire} = 0.20\,\text{m}$$
$$\text{resistance of wire} = 50\,\text{m}\Omega$$
$$\text{diameter of wire} = 0.36\,\text{mm}$$

Determine the metal of the wire using information from the table below.

Metal	Resistivity / $\Omega\,\text{m}$
aluminium	2.7×10^{-8}
tungsten	5.6×10^{-8}
iron	1.0×10^{-7}

(3)

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

$$50 \times 10^{-3} = \frac{\rho \times 0.20}{\pi \left(\frac{0.36 \times 10^{-3}}{2}\right)^2}$$

$$\rho = 2.54 \times 10^{-8} \qquad \therefore \text{tungsten}$$

This candidate has completed a fully correct calculation to gain the correct numerical answer. As the units were given in the table, we did not need to see units on their answer, but this candidate has failed to recognise that the metal is aluminium, so only scores MP1 and MP2.

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

$\rho = \dfrac{RA}{L}$

$\rho = \dfrac{50 \times 10^{-3} \times 4.07 \times 10^{-7}}{0.20}$

$\rho = 1.01 \times 10^{-7}$

$\rho = 1.0 \times 10^{-7}$ so it is iron.

$A = \pi r^2$

$A = \pi \times (3.6 \times 10^{-4})^2 \times 0.20$

$A = 4.14 \times 10^{-8} \ m^2$

$\dfrac{0.36}{1000} = 3.6 \times 10^{-4}$

$A = \pi r^2$

$\pi \times (3.6 \times 10^{-4})^2$

$A = 4.07 \times 10^{-7} \ m^2$

(Total for Question 11 = 3 marks)

This candidate has failed to divide the given diameter by 2 before calculating the cross sectional area. As a result, they ended up with an answer that is 4 times larger than the true value which gives an answer very close to the given value for iron. There is no error carried forward within the question here, so even though their calculated value is closest to iron, they do not score MP3.

Candidates could only achieve MP2 if the value they had inserted for the cross sectional area was in metres squared. So this candidate scored MP2.

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

$$= \frac{50 \times \pi \times (0.18 \times 10^{-4})^2}{0.20}$$

$$= 2.5 \times 10^{-7}$$

Metal is aluminium

Question 12 (a)

A definition of drift velocity should refer to it being the mean or average velocity for charge carriers. In this case, the charge carriers had already been defined as electrons, so a mean or average velocity for the electrons would also be accepted.

12 The equation $I = nqvA$ can be used to establish the drift velocity v of electrons in a copper wire.

(a) State what is meant by drift velocity.

(1)

The average velocity of the electrons flowing in the wire.

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Examiner Comments

This is one of the accepted alternative answers.

Question 12 (b)

This two mark calculation question was generally answered well. The most common mistake was from candidates not recognising that q should be the charge of an electron. Some failed to add units to their answer, and some rearranged the equation incorrectly. A very small minority had difficulty transferring the given values into the equation correctly, eg some used 8.94×10^{28} m^3 instead of 8.49×10^{28} m^3 for n.

(b) A copper wire has a cross-sectional area of 2.64×10^{-7} m^2 and carries a current of 1.31 A. Calculate the drift velocity of the electrons in this copper wire.

$n = 8.49 \times 10^{28}$ m^{-3}

$$1.31 = (8.49 \times 10^{28})(2.64 \times 10^{-7})(6.63 \times 10^{-34})^{(2)} \checkmark$$

$$V = \frac{1.31}{An} = 8.8.2 \times 10^{10}$$

Drift velocity = 8.82×10^{10}

$$I = nqvA$$

$$v = \frac{nqA}{I}$$

$$\frac{(8.49 \times 10^{28} \, m^{-3})(2.64 \times 10^{-7} \, m)(-1.6 \times 10^{-19})}{1.31 \, A}$$

$$= 2737.54$$

Drift velocity = 2737.54 m s⁻¹

$$1.31 = 8.49 \times 10^{28} \times 1.6 \times 10^{-19} \times V \times 2.64 \times 10^{-7}$$

$$V = 3.65 \, ms^{-1} \times 10^{-4}$$

Drift velocity = $3.65 \times 10^{-4} \, ms^{-1}$

Question 13 (a)

Very few candidates realised that the surface area of a sphere ($4\pi r^2$) should be used for the area in the equation, so access to MP2 and MP3 was limited. The vast majority of candidates used πr^2 instead, which restricted them to MP1 only.

13 The orbits of planets around the Sun are elliptical.

The intensity of radiation received at the top of the Earth's atmosphere is monitored during one orbit of the Earth around the Sun.

The following data is recorded:

maximum intensity of radiation = $1.41\,\mathrm{kW\,m^{-2}}$
minimum intensity of radiation = $1.32\,\mathrm{kW\,m^{-2}}$

(a) Calculate the minimum distance between the Earth and the Sun.

power of the Sun = $3.83 \times 10^{26}\,\mathrm{W}$

(3)

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

$$\Rightarrow 1.41 \times 10^3 = \frac{3.83 \times 10^{26}}{4\pi r^2}$$

$$\Rightarrow r = \sqrt{\frac{3.83 \times 10^{26}}{4\pi \times 1.41 \times 10^3}}$$

$$\Rightarrow r = 1.47 \times 10^{11}\,m$$

Minimum distance = $1.47 \times 10^{11}\,m$

For minimum distance, area $=$ $\dfrac{Power}{max\cdot intensity}$ $= \dfrac{3\cdot83\times10^{26}}{1\cdot41\times10^{3}}$

$$= 2\cdot72\times10^{23}\, m^{2}.$$

$\pi r^{2} = 2\cdot72\times10^{23}$

$\Rightarrow r = \sqrt{\dfrac{2\cdot72\times10^{23}}{\pi}}$

$\therefore r = 2\cdot94\times10^{11}\, \cancel{km}\, m$ ~~diameter~~   ~~diameter~~

Minimum distance = $2\cdot94\times10^{11}\, \cancel{km}\, m\cdot$

Question 13 (b)

Although all of the possible total marks for the question were seen regularly, a significant number of candidates either failed to understand the significance of the data given or recognise the fact that the data provided for the Earth in part (a) was given in kW m^{-2} whereas the data for Mars was given in W m^{-2}. Due to the latter issue, a number of candidates concluded that Mars was actually closer to the Sun as they felt it had a higher intensity than Earth. Although it is not expected that candidates know the order of the planets from the Sun, it was surprising to see so many candidates concluding that Mars was closer to the Sun.

When aiming to describe "Mars orbits at a greater distance from the Sun", some candidates used words such as "longer" which are too ambiguous. Longer could imply a longer time as well as a longer distance. Some also related the intensity readings and variations to other aspects such as temperature on the planet, or the surface area of the planet itself.

(b) As Mars orbits the Sun, the intensity of radiation received at the top of its atmosphere varies from 491 W m^{-2} to 711 W m^{-2}. 220

Explain two differences between the orbits of Mars and Earth that can be deduced from this data.

(3)

The orbit of ~~the~~ Mars is further away from the Sun than the Earth so it is having a lower intensity.
The difference between the ~~inter~~ maximum and minimum intensities of the Earth ~~and~~ is smaller than for mars therefore mars has a more eliptical orbit than Earth.

The orbit of Earth is more elliptical than Mars as it has a greater range of intensity radiation. The Earth has a greater distance from the Sun as its maximum intensity is greater. The orbit of Earth has a greater area than the orbit of Mars.

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Examiner Comments

This candidate has recognised that the Earth has a greater intensity, but MP1 requires this to be linked to the Earth being closer to the Sun than Mars, and this candidate says that Earth is at a greater distance. There is also mention of elliptical orbits, but this is also the complete opposite of the correct answer so this example cannot score any marks.

- Mars is closer to the sun than the earth, hence the intensity of the sunlight and radiation is significantly greater than the Earth's.
- the intensity ~~va~~ also varies from 491 Wm^{-2} to 711 Wm^{-2} because of the movement on the orbit around the Sun.

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Examiner Comments

This candidate has assumed that the intensity on Mars is greater and has made an incorrect conclusion regarding the relative distances of Mars and Earth from the Sun as a result.

Although mention of the variation of intensities on Mars has been made, there is no comparison of this with the Earth so MP3 cannot be achieved either.

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Examiner Tip

Care needs to be taken with prefixes on given values, whether in given data or from the axes of graphs.

Question 14

This is the 6 mark linkage question, which assesses the candidate's ability to show a coherent and logically-structured answer with linkages and fully-sustained reasoning. The topic chosen for this question on this paper was the photoelectric effect, and the evidence to show that a particle-like, rather than wave-like, nature is displayed in this experiment.

Essentially, the mark scheme is divided up so that there are 6 individual indicative content points (labelled as IC points in the descriptions of the scripts). The table in the mark scheme shows how the marks for the indicative content are generated from the number of IC points seen, and this gives a maximum of 4 marks when all 6 IC points have been achieved. On top of that, either 1 or 2 linkage marks may be awarded on the basis of how well the IC points are linked to each other.

On this paper, it was considered that the IC points came in pairs, one of each describing what happens in reality (the particle model), whilst the other described what would happen if the wave model were correct. As such, it was possible to achieve 1 linkage mark for correctly linking just 2 IC points if they were in the same pair. Another linkage could be awarded for linking another pair of IC points as long as 5 or 6 IC points were seen in total on the paper.

Seeing as all of the IC points referred to release of electrons, it would be unfair to prevent a candidate from getting all of the marks for forgetting to mention this in relation to every point. Therefore, if there was clear reference to electrons being released within the answer, then the IC points could be awarded even if not individually linked to electron release.

Many candidates were clearly discussing how line spectra are produced, with descriptions of energy level changes. Some even mixed this with correct descriptions of the photoelectric effect.

*14 In 1921, Albert Einstein was awarded the Nobel Prize for Physics "for his discovery of the law of the photoelectric effect".

To explain this effect, Einstein proposed that electromagnetic radiation should be modelled as a particle rather than as a wave.

Explain why, when considering the photoelectric effect, treating electromagnetic radiation as a particle is a more successful model than treating electromagnetic radiation as a wave.

(6)

When shining UV light onto the surface of a metal, if the light has passed a certain threshold frequency the electrons absorb energy equal to or more than the work function energy and get excited and are emitted from the metal surface. If light was a wave then electron emission would be possible with all frequencies provided it is strong enough (high intensity). This is not the case. This suggests that light carries energies in packets called photons and one electron only absorbs all the energy of a single photon at a time. The energy of a photon is dependant on its frequency $E = hf$ and therefore when the photon has a frequency passed a certain threshold frequency it will have sufficient energy for the electron to absorb and be emitted from the metal surface.

This candidate has clearly mentioned that, in order for electrons to be emitted from the metal surface, the light has to be beyond a threshold frequency. They have also made it clear that any frequency would be able to emit electrons if the wave theory were correct.

This scores IC1 and IC2, meaning 2 physics marks are awarded. They are linked points, so a linkage mark is also awarded.

There is no key information about the timing of release or what affects the kinetic energy of the released electrons, so no further IC points are seen and a total of 3 marks is achieved.

Treating it as a particle is more successfull ~~as because~~ when UV light hits the surface of the metal considering photoelectric effect, the frequency of light should be greater than the threshold frequency, each photon ~~emits~~ hits one electron, hf or energy of UV should be greater than the workfunction which is minimum energy required to remove an electron. As frequency increases the kinetic energy increases as $E = hf$, Intensity is just number of electrons emmitted per second. E ~~&~~ Photoelectric effect electrons are emmitted instantly. ~~&~~ Electrons emitted are photo electrons and only emit when $hf > \phi$.

However the wave model suggests that incoming ~~waves come~~ eventually ~~g~~ allow the electrons to gain enough energy and then it's emitted as photoelectrons and that it's frequency has nothing to do with energy of electron. It also states that if intensity increases energy of electrons increases ~~b~~ and this doesn't happen.

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Examiner Comments

This is a very good, clear answer. The candidate has made a number of comparisons and has very nearly achieved all of the marks.

In lines 2-3 IC1 is achieved for a clear description of threshold frequency.

In lines 6-7 IC5 is achieved. Although no credit was given in this question for stating that higher frequencies led to higher photon energy, this candidate is clearly talking about the higher frequency leading to higher kinetic energy (of electrons).

In lines 8-9 IC3 is achieved.

In lines 11-12 IC4 is achieved.

Lines 13-14 do not get IC2 as it has not been made clear enough that any frequency would be able to release electrons in the wave model.

Lines 15-16 score IC6.

With 5 IC points, this scores 3 physics marks. As there are clearly two linked pairs (IC3 & 4, IC5 & 6), 2 linkage marks are awarded (as the written work is clear).

As such, this example scores 5 marks in total.

- During photoelectric effect, electromagnetic radiation is more convenient as particles because, they contain energy that is delivered to the electrons. One photon collides with one electron at a time. If the frequency of the radiation is above the threshold frequency, then the electrons are emitted from the surface as photoelectrons. There is no delay between illumination & emission. But when electromagnetic radiation is used as a wave, it takes time for the electrons to accumulate all the energy. It requires time to be released. Also as waves, electrons can be emitted at any frequency. No particular startup frequency is required.

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Examiner Comments

Although relatively short, this answer includes all of the first 4 IC points from the mark scheme, and is quite clearly described. 4 IC points leads to 3 physics marks. However, this number of IC points can only allow candidates access to 1 linkage mark, even though this candidate has made two separate linked pairs (IC1 & IC2, IC3 & IC4). So the total mark here is 4.

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Examiner Tip

If an answer is written in a confusing way, with the steps in the answer not being in a coherent and logically-structured way, linkage marks are not automatically awarded. Although the answer here is logical, it is still possible to not award a linkage mark in certain cases.

Question 15 (a)

Specification point 68 refers to the ability to derive equations for combining resistances in series and parallel using the principles of charge and energy conservation. This question requested candidates to derive the formula for resistors in series. As the derivation is expected, candidates are not given the equation in the formula sheet, so a lot of the candidates who scored one mark on this question gained it by just being aware that $R_T = R_1 + R_2$.

There were some clear attempts from candidates to work backwards from the answer in order to establish the steps along the way, but most of these were unsuccessful as they mostly started off by replacing R with V/I.

15 Resistors are included in circuits that are used as potential dividers.

(a) Derive an equation for the combined resistance R_T for two resistors, R_1 and R_2, in series.

(3)

$$R_T = R_1 + R_2 \qquad\qquad R = \frac{\rho \ell}{A}$$

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A number of candidates, such as this one, could recall the equation for resistors in series without being aware of how it was derived. This still scored MP3, however, as the equation is not an equation provided in the formulae given.

(a) Derive an equation for the combined resistance R_T for two resistors, R_1 and R_2, in series.

(3)

$$R_T = R_1 + R_2 \qquad R = \rho \ell$$

$$\frac{1}{R} = \frac{1}{R_+} + \frac{1}{R_1 + R_2}$$

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Examiner Comments

This candidate was unsure about which equation was for series and which was for parallel. The correct formula has been scribbled out and replaced with a parallel formula.

(a) Derive an equation for the combined resistance R_T for two resistors, R_1 and R_2, in series.

(3)

$$R_1 + R_2 = R_T$$

$$V_1 = IR_1 \qquad\qquad V_2 = IR_2$$

$$V_T = IR_T = V_1 + V_2 = IR_T$$

$$IR_1 + IR_2 = IR_T$$

$$R_1 + R_2 = R_T$$

Question 15 (b)

Although almost half of the candidates scored all 3 marks on this question, virtually all of the remaining candidates scored either 0 or 1. This was largely due to an inability to combine the formulae for resistors in parallel with resistors in series. There were many different routes to achieve the final answer, but all of them required candidates to undertake the steps shown in one of the two alternatives on the mark scheme. The majority of candidates answered the question using the method shown first in the mark scheme.

(b) The diagram shows a circuit that includes a resistor combination. The battery has negligible internal resistance.
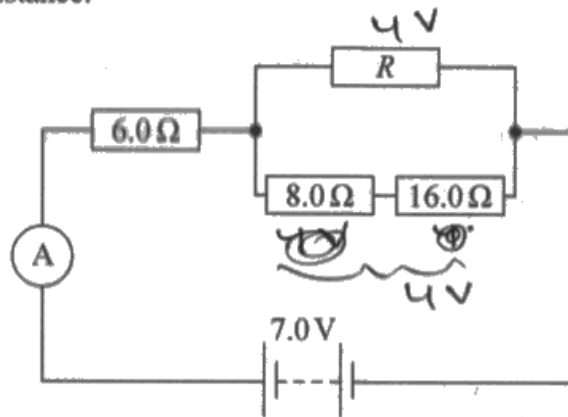
The ammeter displays a current of 0.50 A.

Calculate the resistance R.

(3)

for 6.0Ω $V = 0.5 \times 6 = 3V$

For 8.0Ω, 16.0Ω combined $I = \frac{4}{24} = \frac{1}{6}$

So   for R $I = 0.5 - \frac{1}{6} = \frac{1}{3} A$

$R = \frac{4}{\frac{1}{3}} = 12 \, \Omega$

Resistance R =   12 Ω

The method used by this candidate is the one seen on the second alternative on the mark scheme. They have calculated the potential difference across the 6 Ohm resistor, then subtracted it from 7V to get the p.d. across the parallel combination. This has enabled them to work out the current in each branch of the parallel section, which leads on to a correct answer.

Calculate the resistance R.

(3)

$R_{TOTAL} = \dfrac{7}{0.5}$

$= 14\,\Omega$

$14 - 6 = 8\,\Omega$

$\dfrac{1}{R_{TOTAL}} = \dfrac{1}{R} + \dfrac{1}{24}$

$\dfrac{1}{8} = \dfrac{1}{R} + \dfrac{1}{24}$

$\dfrac{1}{R} = \dfrac{1}{12}$ $R = 12\,\Omega$

Resistance R = ...12 Ω.............

This is the first alternative on the mark scheme. This alternative links much more closely with part (a), where candidates had to show how to derive the formula for resistors in series. This candidate has initially calculated the whole circuit resistance, then subtracted the value of the series resistor to enable the resistance for the parallel section to be determined.

From this point onwards, the resistors in parallel formula is used to achieve the correct answer.

Calculate the resistance R.

(3)

$$R = \frac{V}{I} = \frac{7}{0.5} = 14\Omega$$

$$U = R \cdot I = 6 \cdot 0.5 = \cancel{} 3V$$

$$8\Omega + 16\Omega = 24\Omega$$

$$\frac{1}{24} + \frac{1}{R} = \frac{1}{7}$$

Resistance R = ...

Question 15 (c) (i)

This question also had a couple of alternative ways of achieving the correct answer. Although the ideal equation to use for method 1 was P = I²R as the resistance was a fixed value, some candidates still calculated both the circuit current and the p.d. across the resistor in order to calculate power using *P = VI*. The most frequent mistakes were failing to calculate the whole circuit current correctly, or using the total resistance of the circuit to calculate the power of the fixed resistor.

(c) The circuit shown below includes a light dependent resistor (LDR). The battery has no internal resistance.

(i) In normal daylight, this particular type of LDR has a resistance of 670 Ω.

Calculate the power dissipated in the fixed resistor in normal daylight.

resistance of fixed resistor = 8.00 kΩ

(3)

$R_T = 8670\ \Omega$

$I = V/R$ $\therefore I = 1.38 \times 10^{-3}$ A

$P = IV$.

$= (1.38 \times 10^{-3}) \times 12$.

$= 0.01656$ W

0.017 W

Power = ~~0.0166 W~~ .

Although no numbers are seen being inserted into the calculation, this candidate has clearly established the current for the whole circuit (this is MP1 on the first alternative shown on the mark scheme). They then use P = VI to score MP2. However, they have used the full 12 V, which is not the p.d. across the fixed resistor, so the answer is too large and does not score MP3.

12.0 V

8 kΩ

670 Ω.

(i) In normal daylight, this particular type of LDR has a resistance of 670Ω.

Calculate the power dissipated in the fixed resistor in normal daylight.

$V = IR$

resistance of fixed resistor = 8.00 kΩ

(3)

$$P = I^2 R \quad , \quad I = \frac{V}{R} = \frac{12}{8000 + 670} = \frac{2}{1445}$$

$$So, \; P = \left(\frac{2}{1445}\right)^2 \times 8000 = 0.0153 W$$

Power = 0.0153 W.

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Examiner Tip

Final answers should not be left in the form of a fraction. However, during interim calculations such as in this question, fractions are acceptable for values worked out on the way to the answer.

12.0 V

(i) In normal daylight, this particular type of LDR has a resistance of 670 Ω.

Calculate the power dissipated in the fixed resistor in normal daylight.

resistance of fixed resistor = 8.00 kΩ

(3)

$$8000 \, \Omega$$

$$P = \frac{V^2}{R} = \frac{12^2}{8000 + 670} = 0.02 \, W$$

Power = 0.02 W

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Examiner Tip

When "Use of" is stated before an equation on a mark scheme, there need to be dimensionally correct substitutions into the equation. In this example, it is clear that the value inserted for V is a value from the question, as is the combined resistance inserted for R.

12.0 V

$800 \times 10^3 \, \Omega$

$670 \, \Omega$
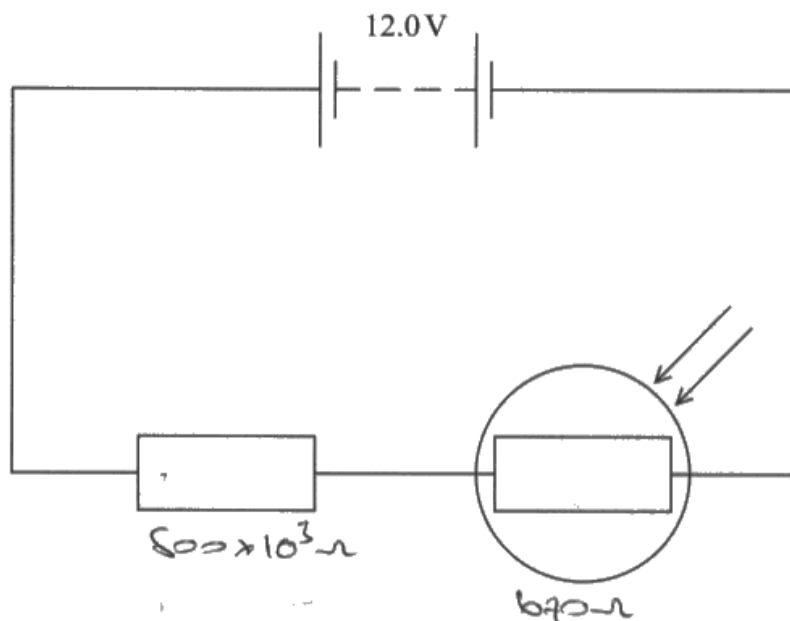
(i) In normal daylight, this particular type of LDR has a resistance of $670\,\Omega$.

Calculate the power dissipated in the <u>fixed resistor</u> in normal daylight.

resistance of fixed resistor = $8.00\,k\Omega$

(3)

$800 \times 10^3 + 670 = 8670 \, \Omega$ $V = IR$

$V = IR$ $= 1.35 \times 10^{-3} \times 800 \times 10^3$

$I = \dfrac{12}{8670}$ $= 1.35 \times 10^{-3}\,A$ $= 11.07\,V$

$P = VI$

$= 11.07 \times 1.35 \times 10^{-3} = 0.015\,W$

Power = $0.015\,W$

Question 15 (c) (ii)

Many candidates answering this question failed to understand the situation described for this particular question. Of these, quite a few decided to describe throughout their answer the situation that occurs when the light intensity **increases**, which is a standard way to describe how an LDR responds, but this question was asking for what happened when the light intensity decreased. Quite a significant number of candidates also failed to develop their answer in any way to show what would happen to the power of the **fixed resistor**, just concentrating on the LDR. A smaller (but still significant) number of candidates were describing how a filament lamp responds when it gets hotter.

(ii) As the light intensity incident upon the LDR decreases, the power dissipated in the fixed resistor decreases.

Explain why the power in the fixed resistor decreases. Your answer should include reference to the electrons in the LDR.

(4)

As the light intensity increases, ~~temperature~~ the electrons present in the LDR gain energy, so they start vibrating, and collide with each other with greater energy. So as a result, ~~more photo electrons~~ the electrons gain photon energy, this increases the current passing through the LDR. As the current increases, resistance decreases. And as we ~~know~~ know $\Rightarrow$ $P = I^2 R$, so if resistance is decreasing, power will also decrease, as they are directly proportional to each other

As light intensity incident upon the LDR decreases, the number of free electrons in the LDR decreases which means the number of free charge carries per m^3 decreases. Since $I = nAqv$ where n = number of free charge carriers per m^3, current flowing through the LDR decreases. Resistance of LDR increases so p.d. across it increases. Since it is a potential divider circuit, p.d. across the fixed resistor decreases. And since Power dissipated $= \frac{V^2}{R}$, the power in fixed resistor decreases.

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Examiner Comments

An ideal, clear answer scoring all 4 marks. For MP4 the candidate had to show the equation they were using to explain their answer.

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Examiner Tip

On some electricity questions, explanations are aided by showing appropriate equations. However, it needs to be clearly stated how the terms in the equation change in order to gain credit. On this question, it was felt that there was no need for candidates to have to mention that the resistance of a fixed resistor is constant, as this is implied by the component name.

Question 16 (a)

This is a standard description of how visible light is emitted from atoms when they are supplied with energy. In this case it was important to recognise that the electrons colliding with the atoms were transferring energy to the atoms. This marking point was the one that was most commonly not awarded. Most candidates were awarded MP2 for the raising of electrons in energy levels, but some did not then link this to release of **photons** when dropping back down, so did not score MP3.

16 In 1857, Heinrich Geissler invented the first gas discharge tube. A sodium gas discharge tube is shown.
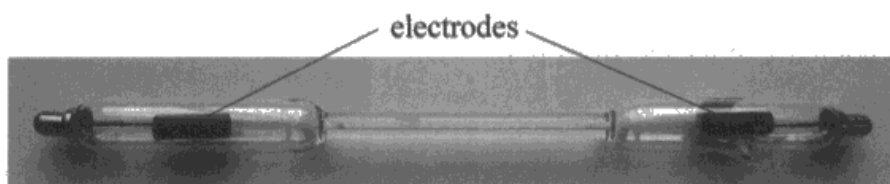
electrodes

When a high potential difference is applied between the electrodes, electrons move through the sodium gas in the tube. The electrons collide with the sodium atoms. The tube then gives out visible light with a wavelength of 589 nm.

(a) Describe the process by which visible light is emitted from the sodium atoms.

(3)

When electrons Sodium atom has discrete energy levels. When electron collides, electron of sodium atom gains energy and jumps to higher energy level. After a while the electron returns to it's ground state by releasing a photon of a specific energy which is the energy difference in energy levels. This photon's frequency falls in visible spectra so we see light.

ResultsPlus
Examiner Comments

A good answer that includes all 3 marking points in the first 5 lines.

when electrons collide they gain energy. And the electrons move to higher energy levels. The electron then moves back to lower energy level and emit energy in the form of visible light. The energy depends on its frequency. Energy is equal to the differences in energy level.
of visible light.

![ResultsPlus Examiner Comments logo]

Examiner Comments

This candidate scores MP1 and MP2, but has not mentioned photons so MP3 is not awarded. Although it is not entirely clear which electrons the candidate is describing when they mention collisions and gaining energy, it was assumed that the electrons in the atoms are gaining energy.

![ResultsPlus Examiner Tip logo]

Examiner Tip

When discussing line spectra, it is important to describe how it is electrons (not atoms) that move up energy levels and back down again.

Question 16 (b)

The majority of candidates appeared to be familiar with such calculations, and 3 marks were commonly seen awarded. The commonest mistakes was from candidates not handling the conversion from J to eV correctly. Some of these simply did not convert at all, but the rest multiplied by 1.6×10^{-19} instead of dividing by it.

(b) Calculate the energy, in eV, of a photon of visible light with a wavelength of 589 nm.

(3)

$$E = hf$$

$$= h \times \frac{v}{\lambda}$$

$$= 6.63 \times 10^{-34} \times \frac{3 \times 10^8}{589 \times 10^{-6}} \times 1.60 \times 10^{-19}$$

$$= 5.403 \times 10^{-41} \text{ eV}$$

Photon energy = 5.403×10^{-41} eV

ResultsPlus
Examiner Comments

The first marking point in the mark scheme involves two equations. Many candidates, such as this one, have combined them together and score MP1. This candidate has incorrectly converted to eV by multiplying rather than dividing, so does not score MP2 or MP3.

(b) Calculate the energy, in eV, of a photon of visible light with a wavelength of 589 nm.

(3)

$1 \, \text{nm} = 10^{-9}$

$E = hf$

$= 6.63 \times 10^{-34} \times 5.09 \times 10^{14}$

$= 3.37 \times 10^{-47} \, \text{J}$

$1 \, \text{eV} = 1.6 \times 10^{-19} \, \text{J}$

$= 3.37 \times 10^{-47} \, \text{J}$

$\simeq 2.109 \times 10^{-28} \, \text{eV}$

$v = f\lambda$

5.89×10^{-7}

$3 \times 10^8 = f \times 5.89 \times 10^{-7}$

$5.09 \times 10^{-14} \, \text{Hz} = f$

Photon energy = 2.109×10^{-28} eV

ResultsPlus
Examiner Comments

Although the final answer looks very wrong, the only mistake made by the candidate is that they have the wrong power on their calculated value for frequency (they have written it with a power of -14 instead of +14). As a result, their final answer is 28 orders of magnitude out.

As with other calculations, such power of 10 errors do not affect the awarding of marking points prior to the answer mark, so this candidate scores MP1 and MP2. The answer is wrong, so no MP3.

(b) Calculate the energy, in eV, of a photon of visible light with a wavelength of 589 nm.

Visible light spectrum.

(3)

$E = \dfrac{hc}{\lambda}$

$1eV = 1.6 \times 10^{-19} J$

$= \dfrac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{589 \times 10^{-9}}$

$3.37 \times 10^{-19} J = \dfrac{3.37 \times 10^{-19}}{1.6 \times 10^{-19}}$

$= 0.0337 \times 10^{-17} J$

$= 2.11 eV$

$= 3.37 \times 10^{-19} J$

Photon energy = ... 2.11 eV . ... eV

Question 16 (c)

The diffraction grating experiment (and equation) were not on the previous specification, and there were clearly some issues with candidates being unable to adapt their practical knowledge to this question. Two distances were provided, which should have been used to calculate the angle θ. However, a significant number of candidates simply used the double slit equation which is not on this specification.

It was also quite clear that many of the candidates were not aware of what each of the letters in the equation represented. Even those who quoted the correct formula then inserted numbers in random locations in order to establish an answer. Many of these candidates were also not exactly clear which letter from the formula they were trying to calculate. A large number inserted the value of *D* into the formula as *d*.

(c) Light from the tube was directed through a diffraction grating, labelled as having 300 lines per mm. The diffraction pattern produced was displayed on a flat screen. The student measured the distance *s* between the central maximum and the first-order maximum on the screen. He also measured the distance *D* from the diffraction grating to the screen.

Determine whether the labelling of the diffraction grating as having 300 lines per mm was correct.

$s = 0.234$ m
$D = 1.30$ m
$\lambda = 589$ nm

(3)

$$n\lambda = d\sin\theta$$

$$300 \times 589 = 1.30 \times \sin 90°$$

ResultsPlus
Examiner Comments

This candidate has identified the correct equation to use in order to answer the question, but has inserted incorrect values in as the terms. The value inserted for n is 300 so the candidate has assumed that n stands for number of slits per mm. Although there are two alternative methods shown on the mark scheme, for MP2 to be awarded both of them require n to be inserted with a value of 1. Thus this candidate scores no marks as there is no attempt to calculate the angle.

$$-) \quad \lambda = \frac{sd}{D} \qquad =) \qquad d = \frac{\lambda D}{s}$$

$$d = \frac{(58 \, 4 \times 10^{-9}) \times 1.30}{0.234} = 3.27 \times 10^{-6} \, m$$

$$-) \quad 300 \, lines = 1 \, mm = 1 \times 10^{-3} \, m$$

$$d = 1 \, lines = \frac{1 \times 10^{-3}}{300} = 3.33 \times 10^{-6} \, m$$

∴ The values are very close together so the labelling is correct

$s = 0.234$ m
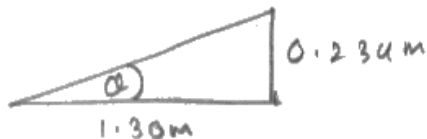$D = 1.30$ m
$\lambda = 589$ nm

0.234 m

1.30m

(3)

$n\lambda = d\sin\alpha$

$\tan\alpha = \dfrac{0.234}{1.30}$ $\alpha = \tan^{-1}\left(\dfrac{0.234}{1.30}\right) = 10.20$

$1 \times 589 \times 10^{-9}$ m $= d \times \sin 10.2$

$d = \cancel{3.32 \times 10^{-6}}$ m 3.3246×10^{-6}
$= 3.32 \times 10^{-6}$

$300 \longrightarrow 1$mm

$300 \longrightarrow 1 \times 10^{-3}$ m

$1 \longrightarrow \dfrac{1 \times 10^{-3} \text{ m}}{300}$

$= 3.33 \times 10^{-6}$ m

Yes the diffraction grating has a
300 lines per mm.

ResultsPlus
Examiner Comments

A fully correct answer for all 3 marks. Although the candidate has not calculated 301 lines per mm, they have worked out the spacing for the lines and compared it to what the spacing would be if 300 lines per mm were used (showing that they are very similar).

Question 17 (a)

Although the diagram was labelled as being "not to scale", it should have been clear to candidates that the point marked O was positioned so that it was an equal distance from each of the loudspeakers; hence the path difference should be 0. Many candidates simply gave a standard description for any position of constructive interference with a path difference of nλ. This was not good enough to explain this particular point of constructive interference. However, a large number of candidates managed to achieve MP2 and MP3.

17 A teacher set up a signal generator connected to two loudspeakers as shown.
This apparatus was used to determine the speed of sound in air in an open space.

A measuring tape was positioned along the ground at XY, which was a perpendicular distance of 3.00 m from the two loudspeakers.
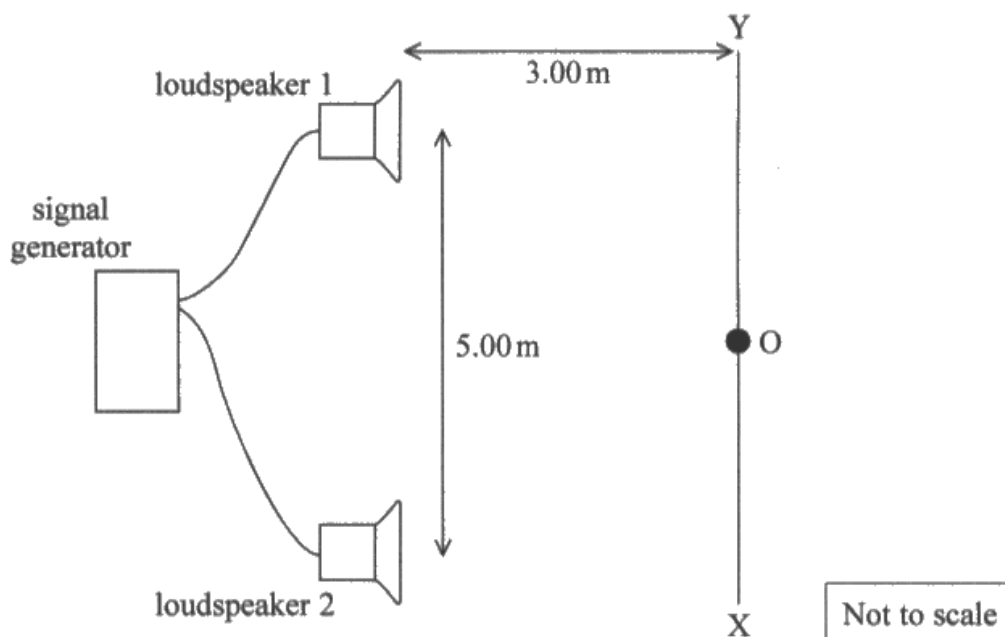
The signal generator was set to a frequency of 160 Hz. The students walked along the line XY. As they walked, they heard a series of loud and quiet sounds. At O the students heard a loud sound.

(a) Explain why the students heard a loud sound at O.

(3)

At point O sound has travelled the same distance from loudspeaker1 a2 so they are in phase and form constructive interference.

The two waves from loud speaker one 1 and 2 diffract. The two waves diffract and superpose. when At the point of the two waves so are in phase (Path difference $n\lambda$) and they superpoase, so contructive interferce occurs. The amplitude of sound is maximum for constructive interference So at O the students heard loud sound. The frequency is greater and than 160 Hz and wavelength is shorter.

Question 17 (b) (i)

This question is representative of the greater demand levels of the new specification. Unfortunately the majority of the candidates were unable to apply the information given to the calculation required, with very few even recognising that the path differences needed to be calculated. Those who did not calculate path lengths typically scored 0 or 1, whilst those who calculated a path length (or both) correctly usually ended up scoring all 5 marks.

A handful of candidates clearly knew the expected value for the speed of sound in air, so tended to try and work back from 340 ms^{-1} (for example) to find out what the wavelength should be.

(b) As the students moved from O towards Y, the sound became quieter until a minimum was reached. One student stood still at the minimum point while another student recorded from the measuring tape the distance from O at which this occurred. He recorded this as 84 cm.

(i) Determine the speed of sound in air.

(5)

distance of wave from loudspeaker 1 = $\sqrt{(3)^2 + (5-2.5-0.84)^2}$

= 3.43 m

distance of wave from loudspeaker 2 = $\sqrt{(3)^2 + (2.5+0.84)^2}$

= 4.89 m

∴ path difference = 4.49 - 3.43

= 1.06 m

∴ wavelength = 1.06 × 2 = 2.12 m

v = f λ

= 160 × 2.12

= 339.2 ms^{-1}

Speed of sound in air = 339.2 ms^{-1}

$$\lambda = \frac{xd}{D}$$

$$v = f\lambda$$

$$v = 160 \times 1.4$$

$$\lambda = \frac{5 \times 0.84}{3}$$

$$v = 224 \, ms^{-1}$$

$$\lambda = 1.4 \, m$$

Speed of sound in air = $224 \, ms^{-1}$

Question 17 (b) (ii)

Although the mark scheme shows three different alternatives of how the marks could be gained on this question, the majority were writing answers that applied to the first alternative. These often did not score marks due to incorrect usage of language. The vast majority of answers seemed to be answering a different question so were literally explaining why dataloggers linked to a computer are better than humans at measuring things.

(ii) The teacher suggested using a microphone connected to an oscilloscope to determine where the loud and quiet zones were located along the line XY. She said that this method would result in much less uncertainty than when students walked along the line XY.

Explain one reason why this is a suitable suggestion.

(2)

Students need to use their own judgement in order to differentiate between almost maximum loudness and actual maximum loudness. So this kind of determination gives a high uncertainty. Using an oscilloscope gives much less uncertainty as maximum amplitude can be determined accurately.

ResultsPlus
Examiner Comments

This is a 2 mark answer via the first method shown on the mark scheme. The first couple of lines score MP1, and the last couple of lines get MP2.

The oscilloscope screen would show a peak at maximum loudness and also show minimum loudness more accurately. Human errors will be eliminated.

ResultsPlus
Examiner Comments

Although MP2 is achieved in this example, the description of human error is not good enough to gain credit for MP1.

ResultsPlus
Examiner Tip

When answering questions about practical procedures and their alternatives, human error is not likely to be accepted as it is not clear enough what the human "error" is in this case. The answer needs to be more specific.

Question 17 (c)

The main expectation for MP1 was that candidates should talk about waves being reflected or echoed, and the fact that they were reflected/echoed from the walls or ceilings in the classroom. Many candidates simply referred to waves "bouncing" off the walls, or simply reflecting (without stating where the reflection was taking place). A small number were clearly writing about diffraction affecting the results, which did not gain credit.

(c) A student suggested that equally valid results would be obtained if the experiment was performed in the classroom.

Criticise this suggestion.

(2)

It would be inaccurate as sound could echo and interfere with the two original waves Some sound energy may be absorbed

ResultsPlus
Examiner Comments
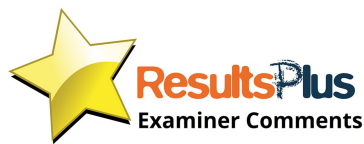
This candidate scores MP2 and very nearly achieves MP1 also. MP2 is for the suggestion that an echoed wave is interfering with the two waves that are already interfering. However, to achieve MP1 it needed to be clear what the sound waves were echoing from.

No, as the sound would bounce of objects making it difficult to create standing wave Can not take large distance as classroom is limited space

ResultsPlus
Examiner Comments

Bounce is not an acceptable alternative to reflect or echo. Additionally, this candidate has not stated what the sound would "bounce" from either, so no marks awarded here.

The wall in the classroom could reflect the sound waves back and superpose with the incident waves which would cause ~~wrong~~ incorrect calculations and measurements in the experiment

Question 18 (a)

A standard description question that was generally answered very well. Both marking points were seen on a regular basis.

18 An endoscope is a medical device that can be used to see inside the digestive system. The endoscope contains bundles of very fine glass fibres. Light is directed into the fibres to illuminate the part of the digestive system being investigated.

Light travels along the glass fibres by total internal reflection.
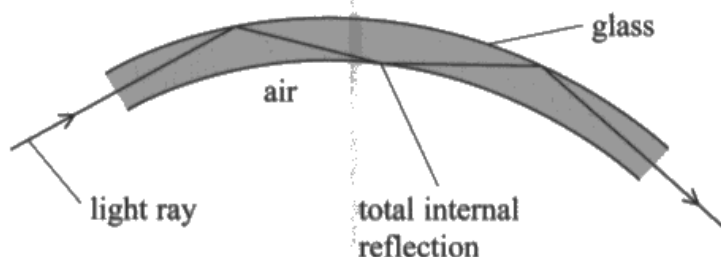
(a) State the conditions required for total internal reflection to occur.

(2)

* The critical angle must be greater than the incident angle.
* The light should travel from ~~dens~~ more denser medium. to ~~t~~ a less denser medium.

RESULTS PLUS
Examiner Comments

The statement about critical angle at the start is unfortunately the wrong way round, so MP2 is not achieved by this candidate. However, they do understand that this occurs at a boundary from a more dense substance to a less dense substance so score MP1.

• The ray must pass through a denser medium to a less dense medium.

• The angle of incidence must be greater than the critical angle.

Question 18 (b)

This question was not answered as well as part (a) and it appears that the majority of candidates were trying to link their descriptions for this part to those for part (a). For example, having said for part (a) that the angle of incidence had to be greater than the critical angle, many then wrote for (b) that the angle of incidence had to be less than the critical angle, which was not relevant to this question.

NOTE :
When reading mark schemes from past papers, it is important to note the context of the question that has been asked. On this question we accepted for MP2 a description that the wave "bends towards the normal". This was only because the candidates had been told in the question that the light refracts as it enters the glass. On another paper, "bends towards the normal" might not be an acceptable answer if the question has not mentioned the name of the process as being refraction.

(b) A ray of light is incident on the end of a glass fibre and refracts as it enters the glass.

Explain why the light refracts as it enters the glass.

(2)

Because it moves from more dense to l when it hits the surface the light bends towards the normal as it ray moves from less to more dense medium

An answer achieving both marks. This is an example where the candidate has just mentioned about light bending towards the normal, rather than refracting towards the normal. However, the word refraction is mentioned in the question so is not expected in the answer.

Angle of incidence is lower than critical angle.
Light is entering a denser medium

As the g to light is going from less dense medium to more dense (meaning refractive index is smaller) it is more likely to refract and enter the glass.

Question 18 (c)

This question represents a multi-step calculation to achieve an answer. To make the question more complex, there are three different materials to consider (air, glass and water). Although the majority of candidates were able to calculate the critical angle at the first boundary, a significant number then used this value as the angle of incidence at the second boundary which was incorrect. A significant number also failed to realise that as the second boundary was between glass and water, both 1.50 and 1.30 needed to be seen inserted as refractive index values in the equation. Having said this, more than 25% of the candidates scored all 4 marks on the question.

(c) The diagram shows a ray of light being totally internally reflected at one side of a glass fibre and then refracting as it leaves the end of the fibre. The angle of incidence at the boundary between the glass fibre and air is equal to the critical angle C for the glass-air interface. The ray enters water as it leaves the glass fibre.
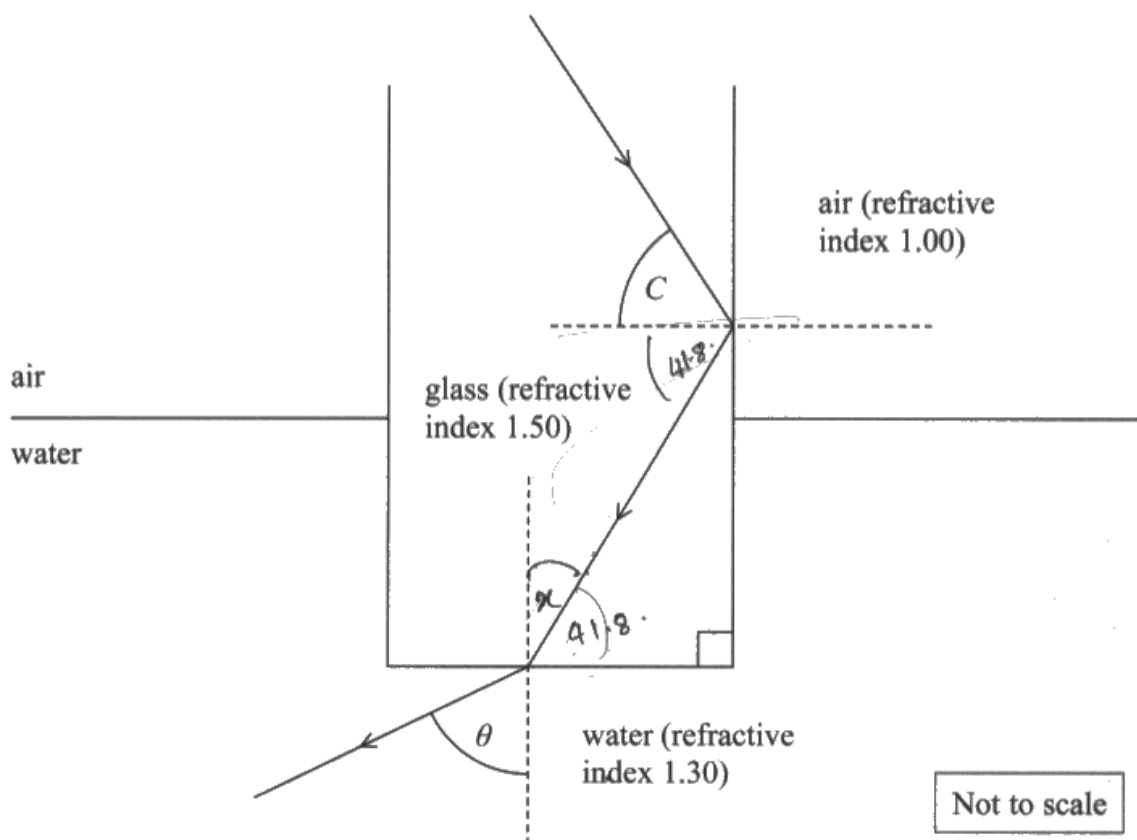
Determine the angle θ between the emerging ray and the normal.

(4)

$$\frac{1}{1.5} = \frac{\sin C}{\sin 90} \qquad\qquad \frac{1.30}{1.50} = \frac{\sin 48.2}{\sin \theta}$$

$$C = \sin^{-1}\left(\frac{\sin 90}{1.5}\right) \qquad\qquad \theta = \sin^{-1}\left(\frac{1.30 \times \sin 48.2}{1.5}\right)$$

$$= 41.8° \qquad\qquad\qquad \theta = 40.24$$

$$= 40.2°$$

$$\therefore x = 90 - 41.8$$

$$= 48.2$$

$$\theta = \underline{\quad 40.2° \quad}$$

$n = \dfrac{1}{\sin c}$

$n = \dfrac{\sin i}{\sin r}$

$\sin c = \dfrac{1}{1.50}$

~~$1.50 = \sin 42$~~

$c = \sin^{-1} 0.667$

$1.50 = \dfrac{\sin 42}{\sin r}$

$= 42°$

$r = \sin^{-1} 0.446$

~~$= 7.8 \times 10$~~

$= 26.5°$

$\theta = \underline{\quad 26.5° \quad}$

$\sin c = \dfrac{1}{n}$

$n_1 \sin \theta_1 = n_2 \sin \theta_2$

$1.5 \times 48.2 = 1.3 \times \sin x$

$c = \sin^{-1}\left(\dfrac{1}{1.5}\right)$

$1.12 = 1.3 \times \sin x$

$\dfrac{1.12}{1.3} = \sin x$

$c = 41.8°$

$90 - 41.8 = 48.2$

$x = \sin^{-1}(0.86)$

$= 59.3°$

$\theta = \underline{\quad 59.3 \quad}$

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

$$n_1 \sin i = n_2 \sin r$$

$$1.5 \sin 41.8 = 1.30 \sin r$$

$$1.90 = \frac{1}{\sin C}$$

$$r = 50.3°$$

$$\theta = 50°$$

$$C = 41.8°$$

$$\theta = \underline{\quad 80° \quad}$$

Question 19 (a)

Questions 19a and 19b refer to Core Practical 8 (Determine the e.m.f. and internal resistance of an electrical cell). As such, it is expected that candidates know how to set up the circuit and interpret a graph of the results.

In Q19a, candidates were asked to complete the circuit diagram. As it was considered that some candidates might find it unusual to try and create a circuit symbol for a potato cell, the cell was drawn in for them. The expected circuit is drawn in the mark scheme. However, quite a few candidates produced a diagram where it would have been impossible to vary the readings for current and potential difference so did not score MP2. Most, however, managed to correctly position the ammeter and the voltmeter. The majority who did not position the voltmeter correctly had placed it around the variable resistor, but had included other resistors in the circuit too.

19 A student carried out an experiment to determine the e.m.f. ε and internal resistance r of a potato cell. The potato used in the experiment was connected to the rest of the circuit using electrodes of two different metals as shown.

electrodes
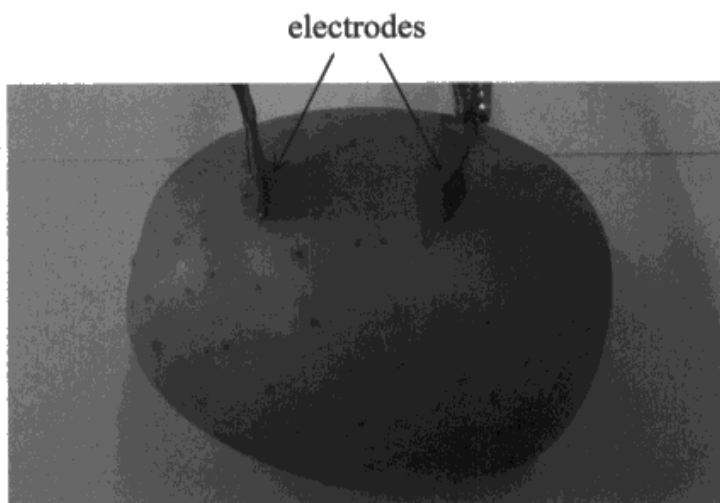
(a) Complete the diagram below to show a circuit that could be used in order to determine ε and r for the potato cell.

(2)

potato cell

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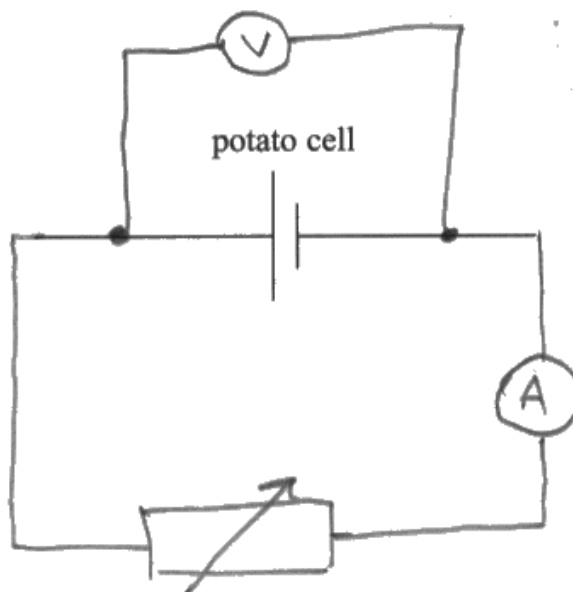
Ideally circuit diagrams would be completed using a pencil and ruler. Although a ruler has not been used for this diagram, it is clearly a circuit containing the correct arrangement of components, so scores both marks.

potato cell

Variable resistor

Reactor

R

A ammeter

V voltmeter

ResultsPlus
Examiner Comments
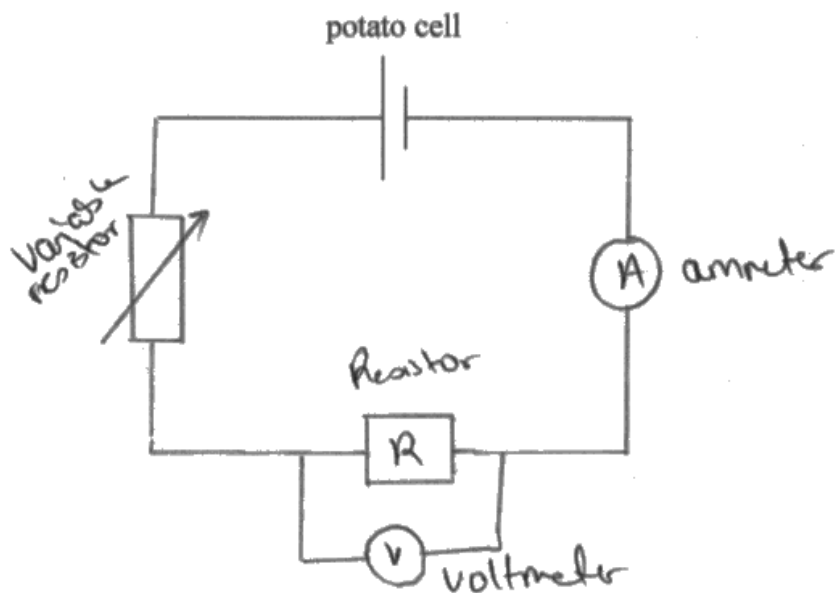
This candidate has drawn the voltmeter around a fixed resistor, and there is another resistor (variable) in the circuit, so the p.d. being measured is not the one required for this practical. As such, MP1 is not achieved. However, there is a variable resistor, so MP2 is achieved.

potato cell


ResultsPlus
Examiner Comments
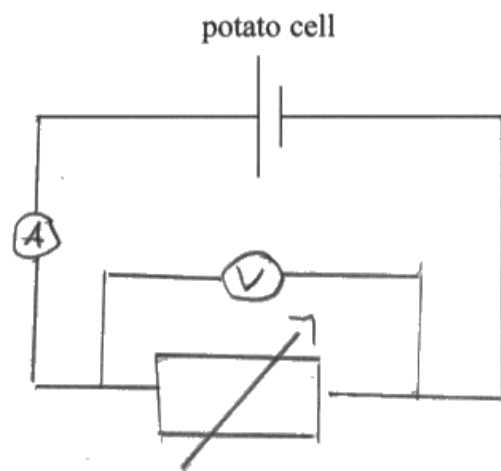
Although the voltmeter is drawn around the variable resistor rather than the cell, there is no other resistive component drawn in the circuit so this is effectively the same as having the voltmeter around the cell. As a result, this candidate scores both marks.

Question 19 (b)

From undertaking the Core Practical, candidates are expected to know that the y-intercept of this graph is the e.m.f. of the cell, and that the gradient is equal to the negative of internal resistance. As such, it was expected that candidates draw a line of best fit in order to enable these values to be established.

Some candidates failed to draw a best fit line, resulting in them being unable to achieve MP1 or MP3. The other two marking points were for correct values for ε and r. A significant number of candidates failed to take into account the current values being in mA, so had a power of 10 error on their answer for r.

(b) The student completed the experiment and plotted a graph showing the relationship between potential difference V and current I as shown.
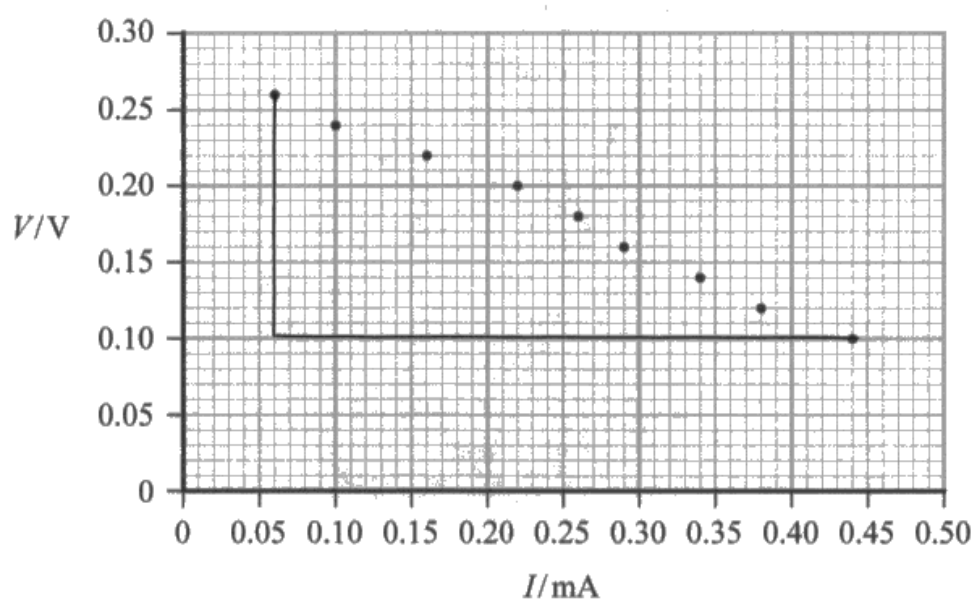
Use the graph to determine values for ε and r.

(4)

$V = \varepsilon - Ir$

$R = \dfrac{V}{I}$, so it is the gradient

$R = \dfrac{0.26 - 0.10}{0.45 - 0.06} = 0.421 \dfrac{0.26 - 0.10}{0.00044 - 0.00006} = 421.0526\ \Omega$

$\varepsilon = V + Ir = 0.16 + 3.8 \times 10^{-4} \times 421.0526 = 0.319 \approx 0.32\,V$

$\varepsilon = \underline{0.32V}$

$r = \underline{421.0526\ \Omega}$

This candidate has not drawn a best fit line for the graph, so cannot score either MP1 nor MP3. Without a best fit line there is no idea whether the data chosen for the "gradient" calculation would have been located on the best fit line.

MP2 is not awarded as the value is out of range.

MP4 is awarded as the internal resistance value is within the given range.

So, this candidate scores 1 mark.

Although this candidate has given the answer for internal resistance to 7 significant figures, it is not penalised on this question. However, candidates should be aware that a number of the answers on WPH13 and WPH16 papers will need to be quoted to the correct number of significant figures otherwise marks will not be awarded.

Use the graph to determine values for ε and r.

(4)
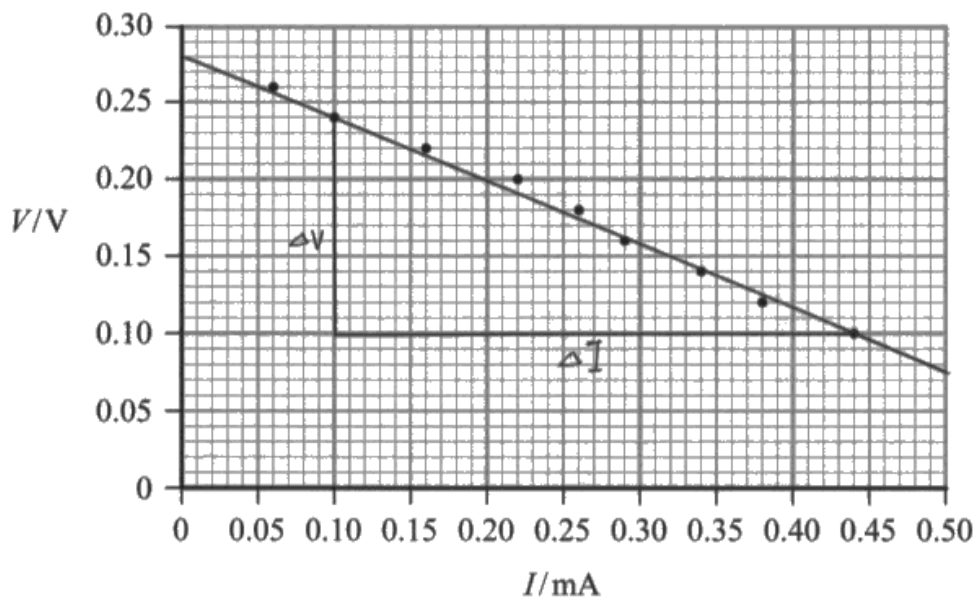
$\varepsilon = 0.28 \text{ V}$

$-r = \dfrac{(0.1 - 0.24) \text{ V}}{(0.44 - 0.1) \times 10^{-3} \text{ A}} = -412 \text{ }\Omega$

$R = 412 \text{ }\Omega$

$\varepsilon = \quad 0.28 \text{ V}$

$r = \quad 412 \text{ }\Omega$

ResultsPlus
Examiner Comments

A very clear 4 mark response, with both answers within the acceptable range.

Question 19 (c)

It is clear that many candidates answering this question did not understand the true meaning of terminal potential difference, with many appearing to describe it as if it were e.m.f. This resulted in quite a few candidates concluding that the terminal potential difference was the same for both circuits, even when they had stated that the total resistance in Circuit A was greater than that in Circuit B.

Many candidates who attempted to use calculations to back up their answer failed to calculate a correct parallel resistance of R/2 for Circuit B. However, as resistors in parallel had already been assessed by calculation in Q15, candidates on this question could still achieve MP1 if they stated that the total resistance in series was greater than the resistance in parallel.

(c) In a separate experiment two resistors, with equal resistance R, are connected to a battery (with internal resistance r) with the two resistors firstly in a series arrangement (diagram A) and then in a parallel arrangement (diagram B).
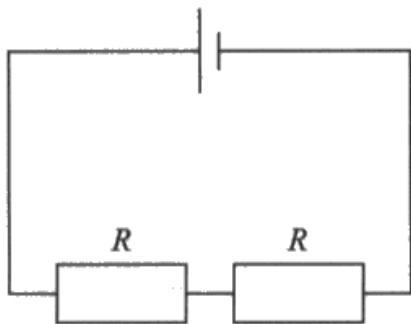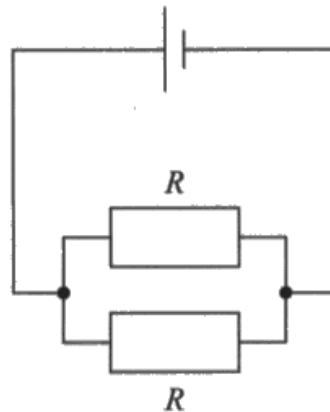

Diagram A   Diagram B

Explain which, if either, of the two arrangements would lead to a greater value for the terminal potential difference.

(4)

p.d.
Terminal! = Emf − Lost Volts .   / Lost Volts = Ir .

Diagram A has greater resistance, so less current flows through circuit in the Diagram A , so lost volts in A is less, [the Emf is same in both circuit] , as the terminal potential difference in A is greater.

· Diagram A will lead to a greater terminal potential difference.
· In a series circuit, the total resistance is greater than that in a parallel circuit.
· So for diagram A, the ratio of the resistors to the ~~ratio of the~~ resistance of the two internal resistance is greater.
· As the resistance is greater, the terminal ~~p.d.~~ potential difference is greater for diagram A as lost volts are ~~less~~ smaller.

Paper Summary

For a first paper on a new specification, candidates showed a generally good understanding of the requirements of the specification. Calculations were generally performed well, and the majority of candidates were aware that the correct units needed to be shown against their numerical answers.

In some cases, answers did not demonstrate a sound understanding of content that was not on the previous specification. In particular, there seemed to be poor understanding of the core practical on diffraction gratings, with many candidates not aware of what the terms in the equation $n\lambda = d \sin \theta$ stood for. In addition, although many knew the formula for resistors in series (Q15(a)), a lot did not seem to know how to derive it.

Some of the more unusual contexts were also not interpreted correctly by candidates, with a number writing answers that would be more appropriate to questions that had appeared on previous exams on the legacy specification.

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

- Ensure that core practicals are undertaken by all candidates and it is fully understood how to interpret the results from such practicals. Answers to Q16(c), 19(a) and 19(b)(i) suggested that a number of candidates were not familiar enough with the core practicals.

- Adapt answers to the questions that have been set. Many of the responses to the linkage question, Q14, were clearly describing the photoelectric effect but were not actually addressing the question asked.

- Make sure that answers use appropriate scientific language, eg on Q17(c) a significant number of candidates described waves "bouncing" off walls rather than "reflecting".

Grade Boundaries

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

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