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Examiners' Report
June 2014

IAL Physics WPH02 01

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Introduction

The assessment structure of Unit 2, Physics at Work consists of Section A with ten multiple choice questions, and Section B with a number of short answer questions followed by some longer, structured questions based on contexts of varying familiarity.

This paper allowed candidates to demonstrate their knowledge of content across the whole specification for this unit, showing progression from GCSE and answering questions to the depth appropriate to their level of understanding.

There was some evidence of candidates quoting answers from mark schemes to previous papers when they were not entirely relevant to the questions in this paper. Whilst past papers and mark schemes are most useful preparation, candidates must use them to help them to learn the Physics rather than learn the actual mark schemes.

A number of responses were seen where candidates recognised the situations and had some recall of techniques, explanations and terminology, but imprecise detail and failure to express themselves clearly prevented the award of marks.

Candidates were sometimes unable to apply their experience of physical phenomena and common magnitudes of quantities to challenge conclusions arrived at by incorrect application of formulae or other reasoning.

Section A - Multiple choice

Question	Percentage of correct responses
1	40
2	74
3	54
4	80
5	88
6	48
7	84
8	92
9	58
10	56

Some questions were more challenging, but the preferred incorrect choices may reveal some areas for development. In the following questions a large majority of candidates with incorrect answers made the same choice.

Q1. More chose the incorrect response, ampere, than the correct response, current. They chose the correct quantity, but selected its unit as the answer.

Q2.The favoured incorrect response was B, so $R = V/I$ was used, but the effect of the internal resistance was ignored and the value of V used was 1.5 V.

Q5.The one in ten who didn't get the correct answer, B, generally chose A. They used current divided by time rather than multiplied by time.

Q6. A was the most common incorrect response, with D very rarely seen, but it probably just shows that they didn't understand because there is no obvious interpretation for selecting the same phase difference at X and Y.

Q10 B was by far the most common incorrect response. This suggests that candidates knew they were looking at $\rho = RA/l$, but misinterpreted the gradient.

Other incorrect choices were more evenly spread.

Question 11

While their answers suggested that most candidates had an appreciation of the basic difference between polarised and unpolarised light, misinterpreting the situation and a lack of detail restricted the awarding of marks.

Many failed to realise that the laser emitted plane polarised light and they thought that unpolarised light was polarised by the filter, quite frequently invoking the action of a second filter after this. It is clear that a substantial number of candidates think that 'polarised' means 'absorbed by a polarising filter'.

Candidates often only stated that the filter only allowed light through in one plane without relating this to the orientation of the plane of oscillation of the laser light, either when it was parallel or perpendicular. Even a candidate quoting the equation $I = I2cos2\theta$ could not take full advantage of this because of defining θ as the angle to the vertical and not relating it to the filter.

Some candidates associated the observations with other phenomena, despite the second word of the question being 'polarising'.

Candidates occasionally drew fairly detailed diagrams. These may help to clarify the situation for the candidates concerned, but without detailed labelling they do not gain marks.

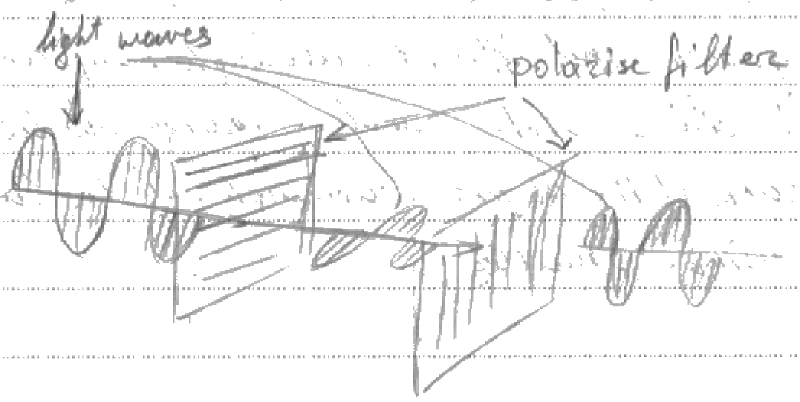
SECTION B

Answer ALL questions in the spaces provided.

11 A polarising filter is placed in front of a laser. When the laser is switched on a red spot is seen on a screen. The filter is then rotated through 180°. As the filter is rotated, the intensity of the red spot falls almost to zero and then returns to the original intensity.

Explain these observations. **(3)**

because polarising filter have got 2



ResultsPlus Examiner Comments

A number of candidates produced diagrams for question 11, this being a fairly complex example. They rarely gained marks for the diagrams as detailed labelling is required. In addition, this diagram seems to represent an unexplained rotation of the plane of polarisation.

ResultsPlus Examiner Tip

If a diagram is used to illustrate an answer, it will not gain marks unless it has detailed labels.

SECTION B

Answer ALL questions in the spaces provided.

11 A polarising filter is placed in front of a laser. When the laser is switched on a red spot is seen on a screen. The filter is then rotated through 180°. As the filter is rotated, the intensity of the red spot falls almost to zero and then returns to the original intensity.

Explain these observations.

(3)

Light can be polarised – travel in one single plane – using filters made of transparent polymers with molecules aligned in one direction. The laser, which is already plane polarised, will be able to pass the filter with equal intensity if the molecules are aligned in the same direction as the plane in which it is polarised. As the filter is rotated the ray will pass through with less intensity (minimum intensity at 90° of rotation) until it has rotated 180°, meaning the molecules are aligned in the same direction again.

ResultsPlus
Examiner Comments

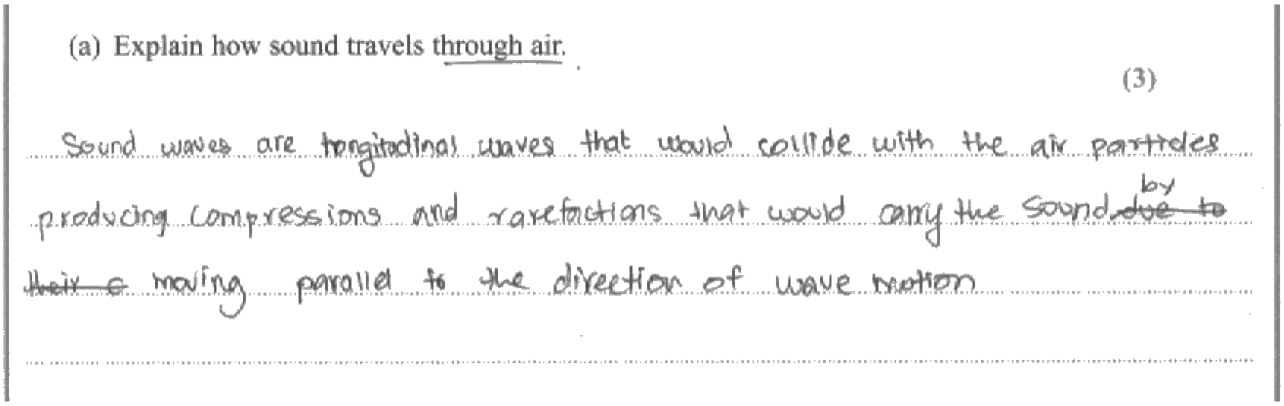
Even though this response starts with an incorrect description of polarised light as travelling in one plane rather than oscillating in one plane, marks are awarded for stating that the laser light is polarised already and describing how it is transmitted by a filter aligned with its plane of polarisation. The situation after 90° of rotation is not described in sufficient detail.

Question 12 (a)

Apart from a few candidates referring to transverse waves, the great majority gained one mark by stating that sound travels as a longitudinal wave, usually mentioning compressions and rarefactions as well.

Only about half went on to get a second mark, however, because of imprecise expression and ambiguous terminology. There was wide appreciation of the relative directions of the oscillations and propagation, but the mark was often not awarded because these were not sufficiently well described. For example, 'movement', 'moves' and 'motion' in this context could apply to the oscillations or the propagation of the wave. 'The movement is in the same direction as the wave' and 'oscillations are parallel to wave motion' are typical examples.

The question specifically asked about sound in air, but relatively few candidates mentioned molecules of air oscillating. Poor expression resulted in a few describing air molecules being compressed individually when they should have been describing regions of compression. Occasionally the answer that 'the wave travels in the direction of energy transfer' is seen.


(a) Explain how sound travels through air.

(3)

Sound waves are longitudinal waves that would collide with the air particles producing compressions and rarefactions that would carry the sound ~~due to~~ by ~~their e~~ moving parallel to the direction of wave motion

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Examiner Comments

This answer scores one mark for longitudinal wave and compressions and rarefactions - different versions of the same mark. Vibrations of air molecules are not mentioned, although the question specifies sound travelling through air. The last part illustrates the ambiguity involved in using the words 'move', 'movement' and 'motion' instead of words such as 'vibrate', 'oscillation' and 'propagation'. This refers to moving parallel to the direction of wave motion, but what is moving, and whether the motion involves the wave itself or the air molecules, is not clear.

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Examiner Tip

When describing transverse and longitudinal waves, avoid the use of the words 'move', 'movement' and 'motion'.

(a) Explain how sound travels through air.

(3)

Sound travels through air by the oscillation of particles parallel to the direction of sound waves, as it is a longitudinal wave.

ResultsPlus
Examiner Comments

This response is credited with 2 marks, but the description, 'parallel to the direction of sound waves' is insufficient. It would need to say 'the direction of travel of the sound waves' at the very least.

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Examiner Tip

This is one of many standard definitions that can be adapted easily to a given context if it has been learned, e.g.: 'Sound travels as a longitudinal wave with oscillations of the (air) particles parallel to the direction of energy transfer'.

Question 12 (b)

The majority of candidates did well on this question overall, with a substantial majority getting at least 2 marks and about half getting 3 or more marks. Candidates did not often make the inverse relationship between the frequency and wavelength explicit. Apart from that, marks were lost for lack of detail such as:

- only discussing pitch rather than frequency
- only discussing wavelength and not mentioning frequency
- only discussing how loud or quiet the sound was, even though Doppler was mentioned in the question
- referring to high and low frequency, but not indicating a change by saying 'higher' and 'lower'.

Quite a few candidates thought there would be a continuous increase of frequency on approach and a continuously decreasing frequency as the train moved away. A few discussed the Blue Shift or Red Shift of the sound!

*(b) Describe and explain what the stationary musicians would hear as the train travelled towards them and then away from them.

(4)

When the train travelled towards them, ~~they~~ the stationary musicians will ~~heard~~ ~~to~~ ~~a~~ hear the sound that graduate getting louder, that means the wave length of the music note is becoming shorter.
when the train travelled away from them, the stationary musicians will hear the sound that graduate getting ~~smaller~~ softer, that means the wave length of the music note is becoming longer as the sound is becoming softer.

(Total for Question 12 = 7 marks)

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Examiner Comments

This answer only refers to the wavelength, whereas we would describe what we hear in terms of frequency. It is therefore limited to one mark. Also, the question is about the Doppler effect, so the comments on loudness, for which there is no attempt at explanation, are not relevant.

*(b) Describe and explain what the stationary musicians would hear as the train travelled person. towards them and then away from them.

(4)

As the train travelled towards ~~them~~ the stationary musicians, the frequency will ~~to~~ increase as the wave length will get shorter and shorter so it decreases. But if the train travelled away from them, the frequency will ~~tend~~ decrease as the wavelength ~~become~~ stretches out and becomes longer so it increases. Frequency is inversely proportional to wavelength.

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Examiner Comments

This scores 4 marks for a well structured answer, addressing all relevant points.

Question 13

The question said, 'Use this information to discuss how scientific ideas develop', but candidates tended to concentrate on the particular case of electron diffraction without general comments, scoring up to 3 marks, or on general discussions, at great length, of the development of scientific ideas without reference to the electrons at all, scoring a single mark.

Overall, the majority gained at least one mark, for their essay on scientific ideas or for stating that electrons have wave properties, but only about a third went on to score more than this.

Discussions of electrons always mentioned that electrons have wave properties but missed the crucial point that this is shown because diffraction is a wave property. Although the question mentioned particles and candidates mentioned waves, they linked them with the idea of wave-particle duality surprisingly rarely. In fact, they often wrote about wave-particle duality for light rather than electrons.

The term 'wavicle' was sometimes used. This term was not sufficient to gain credit and students still needed to state that the properties of both waves and particles are evident.

13 Cathode rays were discovered in 1876. In 1897 J.J. Thomson showed that these rays were made of individual particles. These became known as electrons.

In 1927 at Aberdeen University, diffraction was observed when a beam of electrons was passed through a thin metal film.

Use this information to discuss how scientific ideas develop. Experimental details are not required.

(4)

Electrons behave like waves.
Electrons can pass through the gap between atoms of the metal.
Electrons can interfere constructively and distructively.
When speed of electrons in increased, diffraction will decrease.

ResultsPlus
Examiner Comments

The first sentence scores 1 mark, but the rest isn't used to justify or expand on this statement for further marks.

The final part, presumably linking momentum to wavelength, is beyond the scope of unit 2.

13 Cathode rays were discovered in 1876. In 1897 J.J. Thomson showed that these rays were made of individual particles. These became known as electrons.

In 1927 at Aberdeen University, diffraction was observed when a beam of electrons was passed through a thin metal film.

Use this information to discuss how scientific ideas develop. Experimental details are not required.

(4)

Since diffraction occured when the beam of electrons passed through a thin metal film, we can deduce that electrons behave as both waves and particles because diffraction is a wave phenomenon where a wave finds a gap while travelling ~~at~~ into an obstacle and it spreads out. Electrons and light generally have both particle and wave properties

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Examiner Comments

This answer scores all 3 marks for discussing electron diffraction succinctly, but does not make any statements about the development of scientific ideas.

Question 14 (a)

The majority completed the calculation fully, but some lost marks through not converting from eV to joule. Quite a few neglected to give the unit and so, since a quantity must have a magnitude and a unit, they were not awarded the final mark.

(a) The energy band gap for this material is 2.42 eV.

Calculate the minimum frequency of light required to produce a reduction in resistance.

(3)

$E = hf$

$\frac{1.60 \times 10^{-19}}{6.63 \times 10^{-34}} = \frac{6.63 \times 10^{-34} f}{6.63 \times 10^{-34}}$

$f = 2.413 \times 10^{14}$ Hz

Minimum frequency = 2.413×10^{14} Hz

ResultsPlus
Examiner Comments

This answer completely ignores the value 2.42 eV, although it would have been correct for a value of 1 eV.

(a) The energy band gap for this material is 2.42 eV.

Calculate the minimum frequency of light required to produce a reduction in resistance.

(3)

$E = hf$. $f = \frac{E}{h}$

$= \frac{2.42}{6.63 \times 10^{-34}}$

$= 3.65 \times 10^{33}$

Minimum frequency = 3.65×10^{33}

ResultsPlus

Examiner Comments

In this response, the conversion from eV to J has not been applied, so it only scores one mark.

The value of h is 6.63×10^{-34} Js, so this should indicate that the units are not consistent when compared with eV.

(a) The energy band gap for this material is 2.42 eV.

Calculate the minimum frequency of light required to produce a reduction in resistance.

(3)

$E = hf$

$E = 2.42 \times 1.6 \times 10^{-19}$

$f = 3.872 \times 10^{-19} / 6.63 \times 10^{-34}$

$= 5.840 \times 10^{14}$

Minimum frequency = 5.84×10^{14}

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Examiner Comments

The calculation is correct, but the unit, Hz, has been omitted.

ResultsPlus

Examiner Tip

Physical quantities must have a magnitude and unit. If the unit is omitted, the mark will not be awarded.

Question 14 (b)

Candidates most frequently gained a mark for quoting $R = \rho l/A$ and linking the length to resistance. Surprisingly, this did not stop the same candidates from saying how the shape produced a large surface area so more charge carriers were available. There was plainly some confusion between surface area and cross sectional-area, although it was being applied in the wrong sense in this case. The connection between being thin and having large resistance was less often made, and even less often was the fact that being thin resulted in a smaller cross-sectional area.

A number of candidates gave entirely descriptive answers without reference to the equation, referring to electrons squeezing through a thinner shape, for example.

*(b) The LDR is made of a long, thin zigzag line of semiconducting material on a non-conducting base.

Explain how this design ensures the LDR has the maximum resistance at any given light intensity.

(3)

It ensures that the LDR has ~~a~~ the maximum resistance at any given light intensity as it increases the ~~area~~ length so $R = \frac{\rho l}{A}$, the larger the length, the higher the resistance it would be.

As well, it maximises the area, so that the max light can be received.

ResultsPlus

Examiner Comments

This addresses the length correctly, with a relevant reference to the resistance equation. The area referred to is the wrong area, however, despite quoting the equation. The discussion should be about cross-sectional area.

ResultsPlus

Examiner Tip

It is very often useful to quote equations when explaining phenomena, but be sure you know exactly what each of the symbols represents.

*(b) The LDR is made of a long, thin zigzag line of semiconducting material on a non-conducting base.

Explain how this design ensures the LDR has the maximum resistance at any given light intensity.

(3)

The zig-zag shape increases the length of the semiconducting material in the small LDR. So the distance for electrons to travel is larger as $R = \frac{\rho l}{A}$, $R \propto l$, when l is higher, the ressistence will also be higher.

Thin means less cross sectional area. As $R = \frac{\rho l}{A}$, $R \propto \frac{1}{A}$, when A is less, ressistence will be higher.

So R_{max} ensured.

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Examiner Comments

A good answer, explaining the effect of length and cross-sectional area. The relevant part of the equation has been extracted to explain each variable in turn.

Question 15 (a)

By far the most common mark was 4 out of 4. Those who didn't score full marks were quite likely to have 1 mark for electrical power input only, although a few used the input value divided by the output value in the efficiency equation.

Calculate the efficiency of the torch bulb.

(4)

$$\text{efficiency} = \frac{\text{useful energy output}}{\text{total energy input}} \times 100\% = \frac{\text{useful power output}}{\text{total power input}} \times 100\%$$

$P = VI = 3.1 \times 0.14 = 0.434\ W$

$W = 1.45 \times 0.11 = 0.1595\ J$

$$\text{efficiency} = \frac{0.434}{0.1595} = 2.72$$

Efficiency = ...

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Examiner Comments

The input and output power have both been calculated correctly, but they have been reversed in the efficiency calculation to give an answer greater then 1, which is not possible.

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Examiner Tip

An efficiency greater than 1, or 100%, means it's time to check your working because it is an impossible answer.

Calculate the efficiency of the torch bulb.

(4)

power output = $1.45\ W\ m^{-2} \times 0.11\ m^2 = 0.1595\ W$

power input = $0.14 \times 3.1 = 0.434\ W$

$\therefore$ efficiency = $\frac{0.1595}{0.434} \times 100\% = 36.751\%$

$\approx$ ~~36.75%~~ 37%

Efficiency = 37%

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Examiner Comments

A straightforward example of a correct answer.

Question 15 (b)

While most showed some appreciation of experimental techniques, they were not always able to identify advantages specific to this context and referred to general methods. Many candidates just assumed that conventional meters are inherently less accurate than the sensors used with data loggers, often suggesting, through the frequency of references to parallax errors, that they could not be digital.

Many points made were not relevant advantages. Many measurements a second are not required here; a major advantage is related to taking measurements over a long period of time rather than to a short one.

Similarly, a person with conventional meters can record the readings in a table. What they can't do is measure current, p.d. and intensity simultaneously and at the precise time indicated by the timer.

(b) Over time, the intensity of the light provided by the torch bulb decreases. The student decides to determine the efficiency over the whole period for which the torch shines.

Explain the advantage of using sensors and dataloggers to make the necessary measurements rather than using conventional meters.

(3)

· Can get more datas in given time.

· More Acurate ~~readings~~ measurements.

· automatic ~~g~~ draw a graph.

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Examiner Comments

This is given 1 mark for the comment about the automatic graphing.

There is no reason to expect the measurements to be more accurate as the sensors used are not necessarily any more accurate than other meters.

(b) Over time, the intensity of the light provided by the torch bulb decreases. The student decides to determine the efficiency over the whole period for which the torch shines.

Explain the advantage of using sensors and dataloggers to make the necessary measurements rather than using conventional meters.

(3)

· Sensors can start measuring automatically and dataloggers will record the data simultaneously.

· Dataloggers can draw a graph helping us make some analyses.

· Meters ~~may~~ have errors like zero error while sensors and dataloggers ~~may~~ don't.

(Total for Question 15 = 7 marks)

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Examiner Comments

This response includes relevant detail about simultaneous and automatic measurements and graphing to get 2 marks.

It cannot be assumed that sensors will not be subject to calibration errors.

Question 16 (a)

Had candidates been required to mark the measured angle, it might be easier to understand the wide range of angles reported. 130° may be from using the wrong part of the protractor scale for 50°, but other angles seen bear no relation to the photograph on the page.

The great majority could use the angles they measured, and over half got a refractive index in the required range, but only about a third managed to get the correct angles and correct refractive index.

Take measurements from the photograph to determine the refractive index of the rinse aid. You must record your measurements.

You may ignore any effect from the container.

(3)

Measurements

$i = 52.1^{0}$, $r = 35.1^{0}$

Calculation

$n = \frac{\sin i}{\sin r} = \frac{\sin 52.1^{0}}{\sin 35.1^{0}} = 1.37$

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Examiner Comments

It is doubtful that an ordinary protractor can be used to measure to 0.1°, but the quality of the image would not justify it even so. This spurious precision nudged these values out of the accepted range, so only 2 marks were obtained.

Take measurements from the photograph to determine the refractive index of the rinse aid. You must record your measurements.

You may ignore any effect from the container.

(3)

Measurements

protractor, ruler, incidence angle, refractive angle.

Calculation

refractive index: $\frac{\sin i}{\sin r} = \frac{\sin 50^\circ}{\sin 35^\circ} = 1.34$

ResultsPlus

Examiner Comments

Fortunately for this candidate, the measurements have been included in the working. The answers in the line for measurements are a mixture of variables and measuring instruments.

Question 16 (b)

Considering that they were effectively using an equation not given, since they rarely quoted sin 90°, it is quite remarkable that nearly three quarters scored full marks on this question.

Marks were occasionally lost for not quoting to the extra significant figure required for 'show that' questions and the connecting steps to achieving 64° were not always made perfectly clear, as required for 'show that'. Excessive rounding within the working caused difficulty for a few. Since the refractive index used was 1.11 and significant figures are important in 'show that' questions, it was hard to see why some candidates chose to use 1.1. Reference to the general mark scheme notes used every year illustrates this.

The dipstick is a clear plastic cylinder with a pointed end that dips into the liquid.

Show that the critical angle for light in the plastic, when surrounded by rinse aid, is about 60°.

speed of light in rinse aid is 2.22×10^8 m s^{-1}

speed of light in plastic is 2.00×10^8 m s^{-1}

(3)

$$\frac{\sin i}{\sin r}$$

$$= \frac{2.22 \times 10^8}{2.00 \times 10^8}$$

$$= 60°$$

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Examiner Comments

The ratio of speeds has been quoted, but not linked to refractive index.

The answer 60° does not gain credit because it has been given in the question. 'Show that' answers need evidence that the answer has been calculated and not copied. 64° would be needed.

ResultsPlus

Examiner Tip

In 'show that' answers, show full working and quote the answer to one significant figure more than quoted in the question. The answer should round to the stated value in the question.

The dipstick is a clear plastic cylinder with a pointed end that dips into the liquid.

Show that the critical angle for light in the plastic, when surrounded by rinse aid, is about 60°.

speed of light in rinse aid is 2.22×10^8 m s^{-1}

speed of light in plastic is 2.00×10^8 m s^{-1}

(3)

$\frac{V_2}{V_1} = \frac{2.00 \times 10^8}{2.22 \times 10^8}$

$= 0.909$. $\therefore$ $n = \frac{1}{\sin C}$

$\therefore$ ~~$A = \frac{1}{\sin C}$~~

$C = \sin^{-1} 0.909$

~~0.9~~

$C = 64.7°$ $\approx 60°$

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Examiner Comments

This gets 2 marks out of 3.

The value of refractive index calculated does not match the rest of the working as it has been shown. Credit is given for use of n = 1/sin c and the correct final answer to the required extra sig figs.

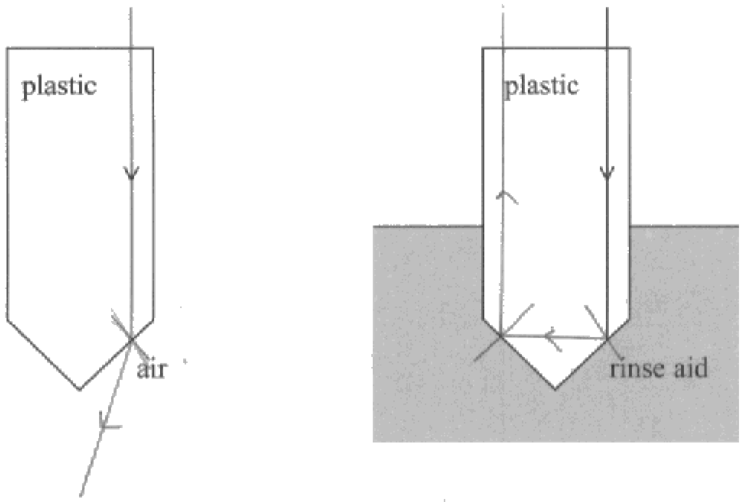
Question 16 (c)

A wide range of diagrams was seen, with the majority scoring at least two marks and a third getting 3 or more. The most common marks were for showing refraction at the surface in rinse aid and total internal reflection at the first surface in air. Occasionally the diagrams were as they should be in the other medium. Reading the notes by the photograph should have let them know these were reversed.

Large numbers of candidates drew a neat normal in the second diagram and then showed refraction towards the normal. This was not careless, but indicates that they could not use the relative speeds of light in the media to determine the direction of refraction. Others drew the refracted ray along the surface in rinse aid, presumably trying to indicate the behaviour at the critical angle.

Various sorts of partial reflection were indicated at times, as well as a sort of optical fibre effect with repeated reflection up the dipstick.

The diagrams below show side views of the dipstick.



Complete the diagrams to show the paths of light when the rinse aid level is low and when it is high.

critical angle for plastic surrounded by air = 42°

(4)

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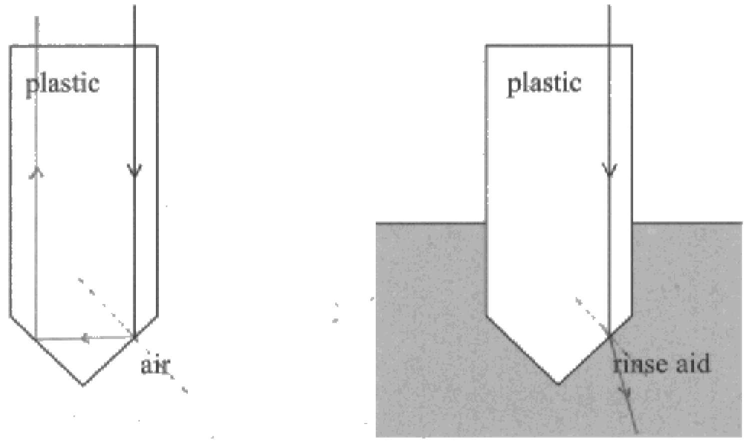
Examiner Comments

This answer is an exact reverse of the correct answer, with each dipstick showing the ray pattern that should be shown by the other.

The diagrams below show side views of the dipstick.



Complete the diagrams to show the paths of light when the rinse aid level is low and when it is high.

critical angle for plastic surrounded by air = 42°

(4)

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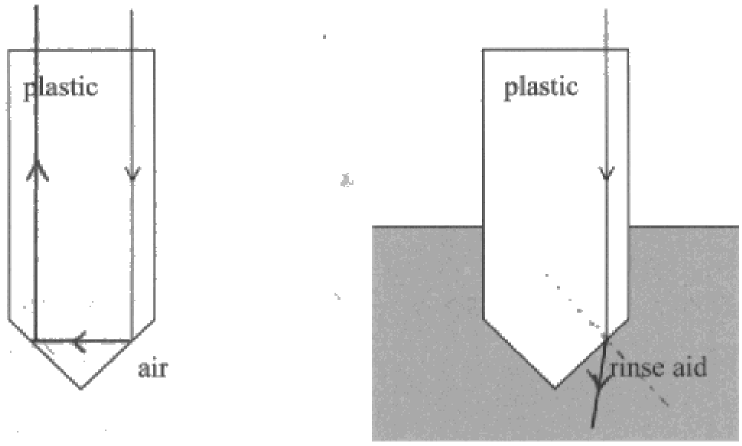
Examiner Comments

The first diagram is correct, but the refraction on the second is towards the normal when it should be away from the normal.

The diagrams below show side views of the dipstick.



Complete the diagrams to show the paths of light when the rinse aid level is low and when it is high.

critical angle for plastic surrounded by air = 42°

(4)

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Examiner Comments

A fully correct example.

Question 17 (a) (i)

Few candidates were unable to apply the speed equation, but a lack of understanding of the situation meant that just under half included the required factor of 2 correctly in their calculation, or for the time or distance they compared with.

The final comparison was rarely correct as candidates did not seem to realise that the pulse duration must be shorter than the time need to get 'there and back' or that the distance ultrasound travels in that time must be less than the total distance 'there and back'. They more frequently thought exactly the reverse of this.

(a) (i) Determine whether a pulse of duration 5×10^{-4} s would be suitable to detect objects as close as 10 cm behind the car.

speed of sound = 330 m s^{-1}

(3)

$t = \frac{s}{v} = \frac{0.1}{330} = 3.03 \times 10^{-4}$ s 3.03×10^{-4} s < 5×10^{-4} s

so a pulse of duration 5×10^{-4} s would be suitable to detect objects are close as 10 cm behind the car.

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Examiner Comments

The factor of 2 has not been included in the calculation, so that calculated time is half what it should be. The calculated time has been compared with the pulse duration and an incorrect conclusion drawn because if the pulse is longer than the time needed it cannot be used. The calculated time should have been compared with half the pulse duration.

(a) (i) Determine whether a pulse of duration 5×10^{-4} s would be suitable to detect objects as close as 10 cm behind the car.

speed of sound = 330 m s^{-1}

(3)

s = ut

time = $\frac{distance}{speed}$ = $\frac{0.1}{330}$ = 3.03×10^{-4} seconds ⇒ $3.03 \times 10^{-4} \times 2 = 6.06 \times 10^{-4}$ s

No, it would not be suitable as a pulse of duration 5×10^{-4} s is shorter than 6.06×10^{-4} s, even if by a very small difference.

ResultsPlus
Examiner Comments

The correct time has been calculated and compared with the pulse duration, but an incorrect conclusion has been given.

Question 17 (a) (ii)

Only about a quarter made a sensible suggestion, such as about the relative wavelengths of the sound and ultrasound. About a quarter of those could say why it was relevant.

A lot just got as far as comparing frequency. Many candidates said that the speed of the waves would differ, generally such that ultrasound was faster, or suggested that audible sound from the environment would cause interference, or that the driver would confuse the sound with the alarm.

(ii) Explain why the reversing sensor would **not** work if it used audible sound rather than ultrasound.

(2)

audible sound has lower frequency and bigger wavelength, this means that it won't work

ResultsPlus

Examiner Comments

The longer wavelength for audible sound has been identified, but no sensible suggestion for why this would make it less effective.

(ii) Explain why the reversing sensor would **not** work if it used audible sound rather than ultrasound.

(2)

Ultrasound is reflected when it reaches a nearby object whereas audible sound (wavelength more similar to size of object) will diffract. This means it's less likely the car will receive a pulse with audible sound. Ultrasound have smaller wavelengths, larger difference to size of objects

ResultsPlus

Examiner Comments

This candidate gives a detailed explanation of the effect of the longer wavelength and scores 2 marks.

Question 17 (b)

Nearly half of the candidates thought of reflection in the wrong direction. Others suggested that reflection wouldn't occur, despite the rest of the question, and the slope suggested refraction to some candidates.

Suggest why the sensor might not detect a sloping object.

(1)

because the sound may not reflect and instead may get refracted

(Total for Question 17 = 6 marks)

ResultsPlus
Examiner Comments

It isn't clear why the sound wouldn't reflect in this situation, but perhaps the candidate is thinking of refraction because of the incident radiation striking the surface at a non-zero angle of incidence.

Suggest why the sensor might not detect a sloping object.

(1)

The sound wave would be reflected downwards (too down for the rear to detect it)

(Total for Question 17 = 6 marks)

ResultsPlus
Examiner Comments

A typical example of a correct answer.

Question 18 (a)

While a majority were able to describe the variation of resistance with temperature for the thermistor, only about half of those who got that right were able to suggest how that linked to the variation in potential difference and its effect on the switch and the heater.

Candidates very rarely explicitly linked the potential difference across AB to the ratio of resistances.

Some candidates used $V = IR$ to link resistance to p.d., implicitly assuming a constant current. Others answered as if the circuit contained a heater and thermistor in series, so that the current would be reduced and the heater turned down as resistance increased. Whether this version was given because they thought the thermistor's resistance increased with increasing temperature, or the thermistor was described thus to maintain consistency with the described circuit, is not clear. If the latter, it should have served to indicate that the answer did not match known information – that thermistor resistance decreases with increasing temperature – and needed reconsidering.

(a) Explain how the circuit will ensure that the insects do not get too hot or too cold.

(4)

The thermistor changes it resistance depending on its temperature, if ~~the~~ it is too cold, the thermistor reduces its ~~to~~ resistivity if it is too cold, and ~~the~~ the circuit flows to power the heater until the thermistor increases its resistivity, i-e the circuit will close until it gets cold enough ~~to reopen again~~ for the circuit to flow again.

ResultsPlus

Examiner Comments

This is an example of an answer where the candidate thinks the variable resistor is controlling the current in the heater circuit directly by using high resistance to decrease current and low resistance to increase it. The thermistor resistance is not varying correctly with temperature. No marks awarded.

(a) Explain how the circuit will ensure that the insects do not get too hot or too cold.

(4)

The NTC thermistor increases its resistance when the temperature decrease. Since Voltage is proportional to resistance ($V=IR$, $V \propto R$) the potential difference across AB increases in cold temperature so the switch goes on and the heating circuit heats the insects. when its too hot the resistance decreases. Therefore, the Potential difference across AB decreases and the switch goes off so the heating circuit goes of and the insects do not get too warm.

ResultsPlus
Examiner Comments

This answer is correct overall, but only links potential difference to resistance in terms of $V = IR$ and not in the sense of a potential divider, gaining 3 marks.

Question 18 (b)

Very few indeed answered this fully, and about a fifth scored a single mark, usually for saying that the heater would not switch off. Many just described the use of a switch in general, for example as a manual override.

(b) Suggest why the switch and heating circuit are included, rather than connecting a heater directly across AB in parallel with the thermistor.

(2)

The potential divider circuit allows for zero values of p.d and maximum values of p.d to be achieved.

ResultsPlus
Examiner Comments

This is given a mark for suggesting that the output p.d. to the heater can be zero with this arrangement, but the effect on the heater is not mentioned.

(b) Suggest why the switch and heating circuit are included, rather than connecting a heater directly across AB in parallel with the thermistor.

(2)

The heater would not switch off and the incests could die from the heat.

ResultsPlus
Examiner Comments

This response suggests the problem with the heater in a different circuit, but it does not explain how the thermistor circuit allows the heater to be switched on and off using the potential divider.

Question 19 (a)

These are standard definitions, but do not always appear to have been learned as such, with only a fifth of the candidates scoring all 3 marks. Most were able to identify a photon as packet of energy or similar, but many seem to think it only applies to light and did not refer to electromagnetic radiation in general. Work function typically did not include ‘minimum’ or ‘surface’.

(a) Explain what is meant by

(i) a photon

(2)

photon is a quantum of energy or a discrete packet of energy.

(ii) the work function

(1)

The minimum energy required to liberate an electron.

ResultsPlus

Examiner Comments

The basic idea of each of the definitions is given, but an essential detail for full marks is missing in each case. For photons this is 'electromagnetic radiation' and for the work function we require 'from the surface'.

ResultsPlus

Examiner Tip

Many standard definitions can be learned for common terms, including photon, work function, diffraction, energy level, superposition etc.

(a) Explain what is meant by

(i) a photon

(2)

A quantum of electromagnetic energy

(ii) the work function

(1)

the minimum amount of energy required to completely remore an electron from a metal surface.

ResultsPlus

Examiner Comments

An example of a fully correct pair of answers.

Question 19 (b)

Two thirds were able to state that an electron is emitted, but only about a third of those linked it to photon absorption clearly. It was often expressed as two events happening at the same time but without a clear causal link, such as 'a photon strikes the dust and an electron is emitted'. The idea of the energy for the photoemission being provided by the photon was often absent entirely, as was any mention of photons at all – despite being mentioned twice on the page. A few got photon and electron mixed up. This may have been because they were trying to explain atomic spectra, which some others who referred to excitation and energy levels clearly were.

Some candidates suggested that charge was transferred to the dust by emitted electrons and others failed to make it clear that removing a negatively charged electron left positively charged dust behind.

(b) Explain how the photoelectric effect could cause the dust to become charged.

(3)

High frequency light, often UV, from the sun will hit the ~~the~~ dust and excite its electrons. If this light has an energy higher than the work function as well as a frequency higher than the threshold frequency, ~~then~~ the dust will emit these electrons causing ~~the~~ it to become positively charged. The electrons emitted are called photoelectrons.

ResultsPlus
Examiner Comments

When the photoelectric effect is being explained, photons and electrons are essential but this doesn't refer to photons.

It says losing the electrons causes it to be positively charged, but doesn't link this to losing negative charge. 1 mark for electron emission only

(b) Explain how the photoelectric effect could cause the dust to become charged.

(3)

The ultraviolet radiation hits on the dust and the electrons absorb the photon and gets liberated. This makes the dust particles charged because the photon transfers energy to the electron and the dust particles loses the electron. Becoming positively charged

ResultsPlus

Examiner Comments

This response scores 2 marks because it explains what happens to photons and electrons, but it still does not link the loss of negative charge to the resulting overall positive charge.

Question 19 (c)

As usual, performance was improved when a calculation was required. Few failed to use $E = hf$ appropriately and nearly 3 in 4 of the entry got as far as the use of the wave equation. Some encountered power of ten problems at this point, although getting impossible answers didn't seem to lead to them trying again, and a number failed to get the mark for the wavelength because they omitted the unit.

About a quarter of the candidates successfully explained why it is a maximum wavelength, with some other candidates stating that it is a maximum failing to establish the link between low wavelength and high photon energy fully. The larger number, however, stated that it is a minimum wavelength for a variety of reasons.

(c) (i) Calculate the wavelength of ultraviolet radiation with photon energy equal to the work function of the dust material.

work function = 6.56×10^{-19} J

(3)

$E = hf$ wavelength: $\frac{c}{f}$

$\frac{E}{h} = f$ $= \frac{(3 \times 10^8)}{9.89}$

$\frac{(6.56 \times 10^{-19})}{(6.63 \times 10^{-34})} = 9.89 \times 10^{14}$ $= 30333670.37$ m

(ii) Explain whether this is a minimum or maximum wavelength for the photoelectric effect to occur in this case.

(2)

This is the maximum wave length for the photoelectric effect to occur because it assumes all photon energy is ~~transferred~~ used for the frequency.

ResultsPlus Examiner Comments

The equations have been applied correctly, but the power of ten applied to the frequency has been emitted in the wavelength calculation. The answer is 30 million metres, and it does not seem to have caused the student any surprise at all when they should be expecting a few hundred nanometres.

The link between photon energy and wavelength has not been described, so there is no mark for stating that it is a maximum without supporting evidence.

ResultsPlus Examiner Tip

It is always worth checking that the answers to calculations represent quantities of reasonable magnitude in the given context and doing the calculation again if they do not.

(c) (i) Calculate the wavelength of ultraviolet radiation with photon energy equal to the work function of the dust material.

work function = 6.56×10^{-19} J

(3)

$hf_0 = \phi$

$h c/\lambda_0 = \phi$

$h c/\lambda_0 = 6.56 \times 10^{-19}$ J

$c/\lambda_0 = 6.56 \times 10^{-19} / 6.63 \times 10^{-34} = 9.89 \times 10^{14}$

$\lambda_0 = 3 \times 10^8 / 9.89 \times 10^{14} = 3.03 \times 10^{-7}$ m.

(ii) Explain whether this is a minimum or maximum wavelength for the photoelectric effect to occur in this case.

(2)

This is the maximum wavelength for photoelectric effect as it provides the minimum frequency for photoelectric effect to occur. As increasing the frequency will decreasing wavelength as they are inversely proportional hence it is the maximum wavelength.

(Total for Question 19 = 11 marks)

$c/\lambda_0 = x$

$\lambda_0 x = c$

$\lambda_0 = c/x$

ResultsPlus

Examiner Comments

This is a well set out example gaining full marks in both sections.

Question 20 (a)

About half of candidates did not score on this question. They often referred to a number of phenomena unconnected with interference, such as polarisation, total internal reflection and atomic spectrum formation. Total internal reflection was used with the idea that different wavelengths would have different critical angles. There were also references to nodes and antinodes and standing waves between the plates.

Of those who realised the question was about interference, most gave an explanation solely related to path difference or an explanation solely related to phase difference, limiting themselves to 4 marks and 3 marks respectively.

Some described path difference as phase difference and vice versa, e.g. 'a phase difference of $n\lambda$' or 'a path difference of π'. The final phase difference mark was sometimes lost by referring to 'out of phase' rather than 'antiphase'. Sometimes $n\lambda/2$ was quoted without making it clear that n is odd for destructive interference.

(a) After combining only certain wavelengths remain.

Explain why certain wavelengths remain but others disappear.

(6)

* when reflection occurs, partial ~~polari~~ polarisation occurs. Thus, they are absorbed by A and B.
* Some hit A and B~~s~~ with an angle greater ~~that~~ than the critical angle and ~~s~~ keep on getting reflected.
* The waves are only transmitted when the ~~critical angle~~ angle is smaller than the critical angle.
* glass absorbs a lot of ultraviolet rays, ~~So some~~ ~~ab~~ thus they 'disappear'.
*

ResultsPlus
Examiner Comments

This is an example of some of the incorrect phenomena used to attempt this explanation. Polarisation, critical angle and absorption are all suggested, but none are relevant.

(a) After combining only certain wavelengths remain.

Explain why certain wavelengths remain but others disappear.

(6)

Certain waves remain because the certain waves are in phase with each other, ~~joing~~ causing superposition to occur, joining the two waves to make a bigger one with more energy. Some waves are not in the same phase with each other when they are near, causing them to be in antiphase, causing interference to occur. This becomes a destructive wave. The waves that are in the same phase are constructive waves. ~~T₁ and T₂ are~~ The constructive wave survive and destructive waves die out.

ResultsPlus

Examiner Comments

This has not been well expressed and gains 3 marks overall for suggesting superposition and linking phase with constructive and destructive interference correctly.

There is no mention of path difference, despite the comment about different path lengths in the question, so 3 of the mark are unobtainable.

(a) After combining only certain wavelengths remain.

Explain why certain wavelengths remain but others disappear.

(6)

When the ~~[illegible]~~ waves combine, they superpose to produce, a resultant wave. If the waves are in anti-phase, then destructive interference occurs so these waves seem to disappear. This only happens when the path difference is an odd number of half wavelengthe. If the waves are in phase, then constructive interference occurs and so these ~~wavelength~~ wavelengths remain to be seen. This only happens if the path difference is an even number of half wavelengths. The certain wavelength's which remain are those where constructive ~~interference~~ interference occurs.

ResultsPlus
Examiner Comments

This is an example of a full mark response. All the relevant points are mentioned and everything is logically ordered, linking each part of the argument to the next.

Question 20 (b)

It was surprising, after many similar questions about spectra in the past, to see that over half failed to score on a question where a standard answer could have scored most of the marks without requiring any particular contextual references.

Overall, about two in five described the emission of a photon, with an electron moving down a level, well enough for a mark. Half of those gained another mark for mentioning discrete energy levels. Rather fewer candidates stated that photon energy = difference in energy levels or explained the limited number of wavelengths. Candidates did not always mention photons at all.

Sometimes marks were not awarded because the discussion centred on limited numbers of energy levels or on hydrogen having one electron and therefore, it was assumed, one energy level or, occasionally, one shell – a clue to the confusion.

$E=hf$ was sometimes quoted without being linked to photon energy.

The photoelectric effect was sometimes described in part and photons were described as changing levels.

There was a possible problem with 'visible' in the question because some just stated that emitted wavelengths were outside the visual range.

(b) Explain why the atomic spectrum of hydrogen only has a number of specific visible wavelengths of light.

(4)

This is because hydrogen has a set number of energy levels. And as its electrons move between these energy levels they release energy that corresponds to these energy levels. These energy changes produce photons of light with specific fequency and wavelength of light that is characteristic of hydrogen.

ResultsPlus

Examiner Comments

This gets close to many of the points, but lacks the detail and clarity of expression to get the marks.

Set numbers of levels isn't sufficient to suggest discrete levels - it's the energies that is important, not the numbers. Again, 'release energy that corresponds to these energy levels' isn't the same as saying the **photon** energy **equals** the **difference** in energy between the levels.

(b) Explain why the atomic spectrum of hydrogen only has a number of specific visible wavelengths of light.

(4)

When electrons in hydrogen are excited, they move up an energy level. When they fall back down, they release their energy in the form of a photon which has energy hf and since h is constant, f is the frequency of light ~~the~~ the electron emits. Since hydrogen has multiple discrete energy levels, the electron can fall down different levels to emit different photons but it can only emit photons

(Total for Question 20 = 10 marks)

with specific energy which is why specific frequencies of light exist and so specific wavelengths of light are seen since the speed of light is constant.

TOTAL FOR SECTION B = 70 MARKS

TOTAL FOR PAPER = 80 MARKS

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Examiner Comments

A good answer overall which scores 3 marks, but it still misses the essential point that the photon energy is determined by the difference in energy between levels and that there are only certain possible differences.

Paper Summary

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

- This paper has demonstrated the need to learn definitions, like photon and work function, thoroughly so they can be quoted fully when required.
- Candidates are encouraged to use past papers and mark schemes, but they should not expect to be able to repeat sections of previous mark schemes verbatim in the answers to new contexts.
- They should learn standard descriptions of physical processes, such as the photoelectric effect and spectrum formation, and be able apply them to specific situations, identifying the parts of the general explanation required to answer the particular question.
- When an answer, numerical or otherwise, appears contrary to general experience, it is usually time to reconsider it.

Grade Boundaries

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

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