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June 2015

IAL Physics WPH02 01

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Introduction

The assessment structure of Unit 2, Physics at Work is the same as that of Unit 1, Physics on the Go, consisting 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.

The paper allowed candidates of all abilities to demonstrate their knowledge and understanding of Physics by applying them to a range of contexts with differing levels of familiarity.

Candidates at the lower end of the range could complete straightforward calculations involving simple substitution and limited rearrangement, including structured series of calculations, but could not always tackle calculations involving several steps, a choice of variables or extra factors, such as the factor of 2 for echo-location. They also knew in outline standard definitions, but often omitted key technical terms, and similarly knew some significant points in explanations linked to standard situations, such as interference, but missed important details and did not always set out their ideas in a logical sequence, sometimes just quoting as many key points as they could remember without particular reference to the context.

Steady improvement was demonstrated in all of these areas through the range of increasing ability and at the higher end all calculations were completed faultlessly; most definitions were given with all the required details and most points were included in ordered explanations of the situations in the questions.

Section A

The multiple choice questions discriminated well, with performance improving across the ability range for all items. Candidates around the E grade boundary typically scored about 6 and A grade candidates usually got 8 or more correct.

The percentages with correct responses for the whole cohort are shown in the table.

Question	Percentage of correct responses
1	73
2	76
3	78
4	75
5	62
6	80
7	54
8	91
9	65
10	81

For some lower scoring questions the frequency of incorrect choices indicates common errors.

Question 5. D was the most commonly chosen incorrect response. For a thermistor, this graph corresponds to resistance against temperature rather than I vs V.

Question 7. The favoured incorrect choice was D. Candidates may be most familiar with the fundamental mode of oscillation of waves on a string and pipes open at both ends, and therefore used to a wavelength of twice the length, and they may have selected D without considering the diagram in detail.

Question 9. Candidates not giving the answer B nearly always chose A, missing the reciprocal when calculating the resistance of the parallel section.

Question 11

About two thirds of candidates got at least one mark by giving the units of area and velocity, but only about a third managed to complete the question fully. Some candidates included all of the units but did not make it explicit to which quantities they referred, so they were not awarded the final mark. Many candidates just ignored the units of *n* and similarly ignored the m^3 they were left with after dealing with the units for *A*, *q* and *v*.

11 The list of data, formulae and relationships states

Current $I = nqvA$

Show that the units on each side of the equation are consistent.

(3)

$Amps = C \times \frac{m}{s} \times m^2$

$Amps = \frac{Coulomb}{s}$

Ampere = coulomb / s

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Examiner Comments

This candidate has one mark for the units of area and velocity, but has ignored *n* entirely and then ignored the units m^3 in stating the final answer. The presence of m^3 might have suggested to the student the need for m^{-3}, and therefore the units of *n*.

11 The list of data, formulae and relationships states

Current $I = nqvA$

Show that the units on each side of the equation are consistent.

(3)

$A = nqvA$

$A = C \times m^2 \times m/s \times 1/m^3$

$A = C/s$

$A = A$

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Examiner Comments

All the correct units have been included, even if $1/m^3$ was added as an afterthought. The question requires the candidate to demonstrate that the equations are consistent, so the link between units and quantities must be unambiguous, hence the requirement to state the units or to put them in the same order as in the equation.

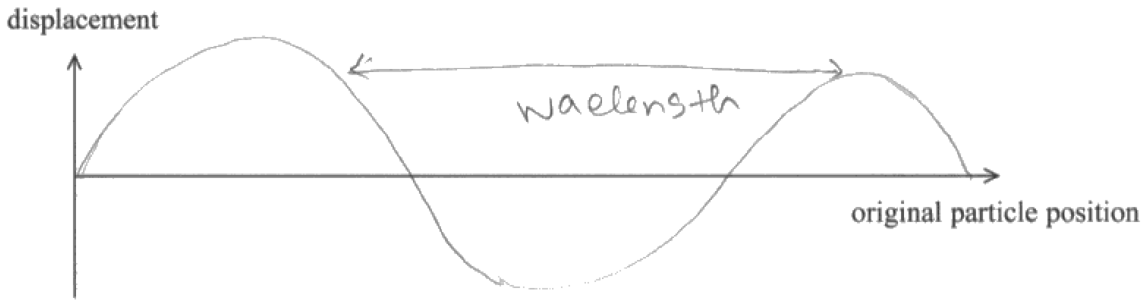
Question 12 (a)

Although one mark was available simply for labelling wavelength on a wave profile, under half of candidates were awarded a mark. A significant minority labelled a wavelength, but only roughly drew their line indicating the wavelength and were not credited. Relatively few students were able to translate displacement correctly from the diagram.

12 The diagram represents the position of particles before a progressive wave passes and as the wave passes.

(a) On the axes below, draw a corresponding graph of displacement against original particle position and label the wavelength.

(2)



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Examiner Comments

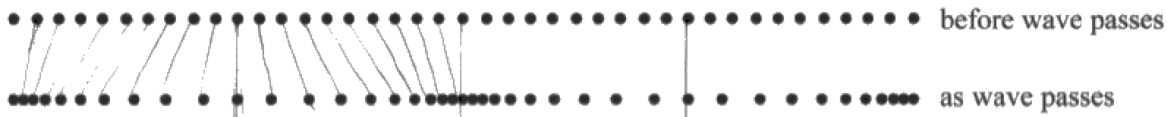
While the wave is poorly drawn, the wavelength mark was still obtainable, but this has not been drawn close to either peak and is too rough to be credited.

ResultsPlus

Examiner Tip

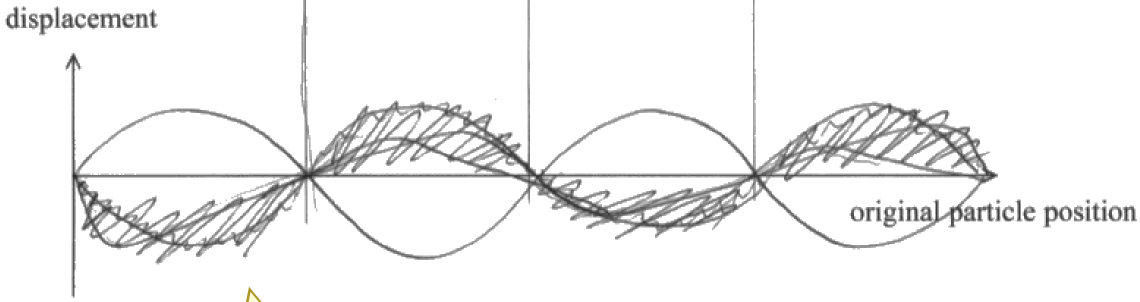
Where appropriate, use rulers for diagrams and mark distances carefully when required.

12 The diagram represents the position of particles before a progressive wave passes and as the wave passes.



(a) On the axes below, draw a corresponding graph of displacement against original particle position and label the wavelength.

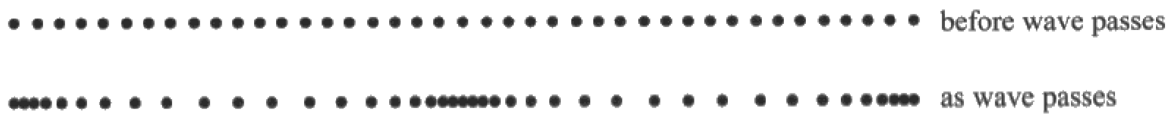
(2)



ResultsPlus
Examiner Comments

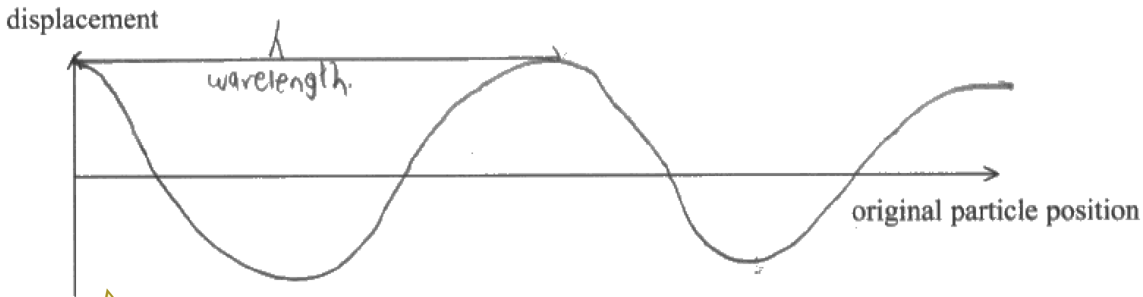
The wave has been drawn very carefully and is completely correct, but the wavelength has not been shown.

12 The diagram represents the position of particles before a progressive wave passes and as the wave passes.



(a) On the axes below, draw a corresponding graph of displacement against original particle position and label the wavelength.

(2)



ResultsPlus
Examiner Comments

The wavelength has been drawn neatly and correctly for one mark. The diagram has the correct two wavelengths, but the initial displacement should be zero, so this should resemble a sine graph rather than a cosine graph.

Question 12 (b)

Three quarters of candidates gave a correct answer. Some candidates gave several answers and were not awarded a mark if any of the suggestions were incorrect.

(b) Suggest what type of progressive wave could be represented by the diagram.

(1)

standing wave

ResultsPlus

Examiner Comments

Despite a progressive wave being asked for, this candidate has suggested a standing wave.

(b) Suggest what type of progressive wave could be represented by the diagram.

(1)

Microwave , Water waves , gamma rays

Ultraviolet

(Total for Question 12 = 3 marks)

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Examiner Comments

Four answers have been given, all of them incorrect. It is never a good idea to include multiple answers because, even if one is correct, if any are incorrect the mark will not be awarded. The examiner will not chose the correct answer from a list.

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Examiner Tip

Do not give multiple answers to questions because one incorrect answer will outweigh any number of correct answers and result in no mark being awarded.

Question 13 (a)

About three quarters of the entry successfully explained the need for pulses. Many gave answers that simply outlined the idea of the pulse-echo technique, e.g. "so that you can record how long it takes for the sent signal to return".

13 Surveyors sometimes use laser rangefinders to measure the distance to objects such as buildings and trees.

A reflector is placed on the object. The rangefinder emits pulses of light and detects them when they return after being reflected.

(a) State why the laser light is emitted in pulses.

(1)

Because the time taken to pulse to return can be calculated more accuratly

ResultsPlus
Examiner Comments

While the suggestion in the answer is a requirement for the technique, there is no suggestion of how using a pulse helps.

13 Surveyors sometimes use laser rangefinders to measure the distance to objects such as buildings and trees.

A reflector is placed on the object. The rangefinder emits pulses of light and detects them when they return after being reflected.

(a) State why the laser light is emitted in pulses.

(1)

To measure the time taken for the return of the Pulse, ~~[illegible]~~ and therefore to find the distance to the object.

ResultsPlus
Examiner Comments

This response gives even more detail on why the time must be measured, but also does not link it to pulses.

ResultsPlus
Examiner Tip

Learn the answers to standard situations such as this.

Question 13 (b)

Only about two thirds of candidates were able to apply the simple speed equation to calculate time, and only about a tenth of them arrived at the correct answer because many did not correctly apply the factor of 2 and others did not select the correct distance. They were supposed to realise that the longest pulse that could be used corresponded to the shortest distance being measured, but many took the range as an indication that they should use the average distance or the difference between the quoted values.

(b) The rangefinder measures distances between 50 cm and 1 km.

Calculate the longest pulse duration that would allow this range of measurements.

(3)

$s = \frac{d}{t}$ $t = \frac{d}{s} = \frac{1000}{3\times10^8}$

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

Pulse duration = 3.33×10^{-6}

ResultsPlus
Examiner Comments

The speed equation has been applied correctly, but the factor of 2 for the distance has not been applied. The correct distance, 50 cm, has not been chosen either.

ResultsPlus
Examiner Tip

Remember that pulse-echo questions will nearly always involve a factor of 2 because distance travelled by the pulse is twice the distance from the emitter to the object.

(b) The rangefinder measures distances between 50 cm and 1 km.

Calculate the longest pulse duration that would allow this range of measurements.

(3)

$v = \frac{2s}{t}$ 3×10^8 = speed of ~~sound~~

6.67×10^{-6}

$t = \frac{2s}{v} = \frac{2\times1000}{3\times10^8} =$ ~~6.06~~ s

6.67×10^{-6} s

Pulse duration = ~~6.06 s~~

ResultsPlus
Examiner Comments

The factor of 2 has been used correctly, but the distance chosen is again incorrect.

(b) The rangefinder measures distances between 50 cm and 1 km.

Calculate the longest pulse duration that would allow this range of measurements.

(3)

Distance = 1000 m − 0.5 m = 999.5 m

2 Distance = speed x time. = $\frac{999.5 \times 2}{3 \times 108} = t$

t = 6.663 x10⁻⁶ sec.

Pulse duration = 6.663x10⁻⁶ s

ResultsPlus

Examiner Comments

This is an example of a student misreading 'between 50 cm and 1 km' and using the difference between these quoted distances. The method is otherwise correct.

(b) The rangefinder measures distances between 50 cm and 1 km.

Calculate the longest pulse duration that would allow this range of measurements.

(3)

$v = \frac{2d}{t}$ ~~0.5~~ 50cm → m

0.5m

$t = \frac{2d}{v} = \frac{2(0.5)}{3 \times 10^8} =$ ~~333333~~ 33.3×10^6

Pulse duration = 33.3×10^6

ResultsPlus

Examiner Comments

The method and distance chosen are correct, but there is a calculation error so the answer is 33.3 million. The unit has been omitted, but a candidate might reasonably be expected to realise that 33.3 million of any sensible time unit is far too long for a laser pulse to measure the distances suggested and to look at the calculation again.

ResultsPlus

Examiner Tip

When an answer is clearly far too large or too small, check your calculations.

Question 13 (c)

Only about one student in twelve made a successful suggestion. Many thought the greater speed of light would be an advantage, but they did not suggest why. A large number assumed that ultrasound had a higher frequency than the light from the laser and that it would also have a shorter wavelength and therefore applied the ideas about diffraction to the wrong wave.

(c) Distances inside buildings, such as the length of a room, are often measured using ultrasound.

Suggest a reason why a laser rangefinder would be more suitable than one using ultrasound for measuring the distance to a tree 1 km away.

(1)

speed of laser is the speed of light, so the speed of a laser is ~~faster~~ greater than the speed of ultrasound so it is faster to use laser.

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Examiner Comments

This candidate is suggesting that the advantage of the laser is that it would be quicker. Over a range of 1 km, the ultrasound would take about 6 seconds, but as the time to make a measurement this is not a major disadvantage. Had the candidate made a suggestion such as that it might be problem keeping a detector in a certain position for this time it could have been a more realistic problem.

(c) Distances inside buildings, such as the length of a room, are often measured using ultrasound.

Suggest a reason why a laser rangefinder would be more suitable than one using ultrasound for measuring the distance to a tree 1 km away.

(1)

The laser has a lower frequency and a larger wavelength so there would be less diffraction in that environment.

(Total for Question 13 = 5 marks)

R
M
IV
V
U
X
G

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Examiner Comments

This starts with two errors, lower frequency and larger wavelength. While one of the suggested answers was linked to less diffraction, this would not be the case with a larger wavelength.

Question 14

While a good majority stated that the oscillations of polarised light are in a single plane or direction, only about half of them went on to gain further marks. Some candidates did not mention oscillations, many of these referring to light travelling in a single plane or direction.

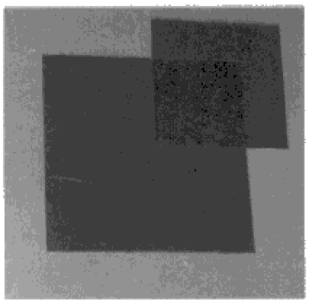
For unpolarised light, some missed the mark through referring to ‘different directions’ or ‘more than one plane’ which were not sufficient for ‘all’ or ‘many'.

Many students missed the third mark because they are thinking of the definition of transverse waves. They commonly say ‘polarised light has oscillations in a single plane which is perpendicular to the direction of propagation of the wave’. The direction of the oscillation at a point is perpendicular to the direction of wave propagation, but along the length of the wave the directions all align in the same plane which contains the direction of wave propagation.

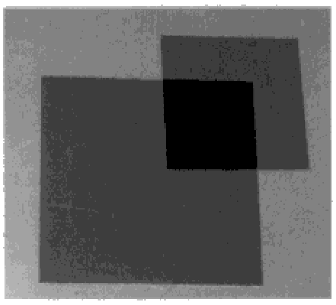
In describing the alignment of the filters, candidates often only referred to the filters themselves and did not discuss the plane of polarisation or the allowed direction of oscillations.

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.

*14 The photographs show two polarising filters on a light background.
Between Photograph 1 and Photograph 2 being taken, one of the polarising filters is rotated through 90°.



Photograph 1



Photograph 2

State what is meant by polarisation and explain the observed difference between the appearance of the polarising filters in the two photographs.

(5)

Polarisation is converting waves that oscillate in different planes to waves that oscillate in a single plane at 90° to the direction of wave propagation.
In photograph 1, the polaroids are at the same angle so light is polarised to one single plane

In photograph 2, the polaroids are adjacent to each other, so it is polarised to one plane by one polaroid, and polarised again by the 2nd polaroid, so no light will come out.

ResultsPlus
Examiner Comments

This response gets one mark for oscillations in a single plane. 'Oscillate in different planes' does not convey the sense of all planes and it has the very common idea that the plane of the oscillation is perpendicular to the direction of propagation.

Saying the polaroids are at the same angle does not include the necessary reference to planes or allowed directions of oscillation.

In the final part, it is not clear what occurs when it is 'polarised again'.

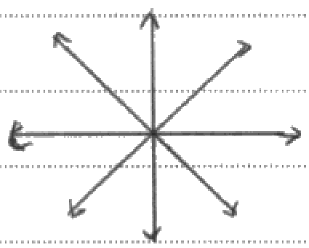
ResultsPlus
Examiner Tip

Remember that, for polarised light, the direction of the oscillations is perpendicular to the direction of wave propagation but the plane of the oscillations includes the direction of wave propagation.

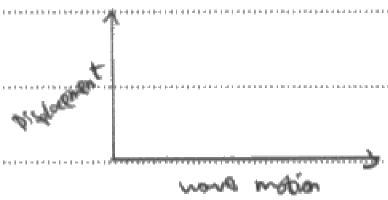
State what is meant by polarisation and explain the observed difference between the appearance of the polarising filters in the two photographs.

(5)

Polarisation is a phenomena occuring in transverse waves. A transverse wave can have oscillations in all directions ~~pass~~ perpendicular to wave motion. When a transverse wave is restricted to oscillate in only one plane perpendicular to wave motion, it is polarised. A polarising filter is used to restrict light to oscillate in one plane perpendicular to wave motion. In photograph 1, the two filters are parallel and thus maximum light is allowed to pass through. In photograph 2, no light passes through as the two filters are perpendicular to each other.



Unpolarised wave



Polarised wave

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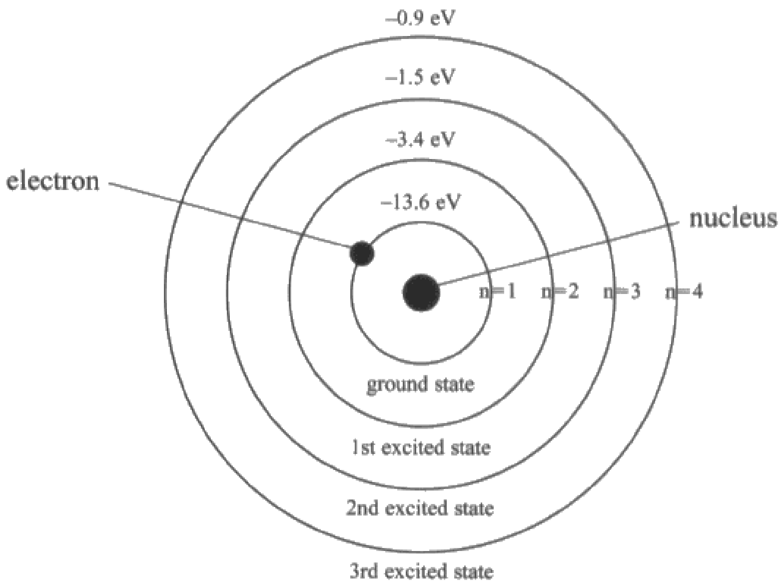
Examiner Comments

This gets the first two marks for the difference between unpolarised and polarised light in terms of the number of planes, even though the initial reference is to directions. This repeats the error that the plane of the oscillation is perpendicular to the direction of propagation. In describing the relative orientation of the filters there is no reference to planes. To say the filters are perpendicular is untrue as that would imply that if one was flat on a page the other would be standing vertically.

Question 15 (a)

About two thirds successfully completed this part. Those who did not generally failed to include 'energy' in their answers, even though they should have received a clue when they looked at part (b). There were some references to terms more associated with Chemistry, such as shells or orbitals, and students studying both will need to be sure to apply the correct terms to the correct subject.

15 In 1913 Niels Bohr proposed the model of the hydrogen atom represented in the diagram.



In this model an electron can orbit the nucleus at different energy levels, some of which are shown in the diagram.

(a) State what is meant by excited with reference to this model.

(1)

Electrons move to a higher orbit.

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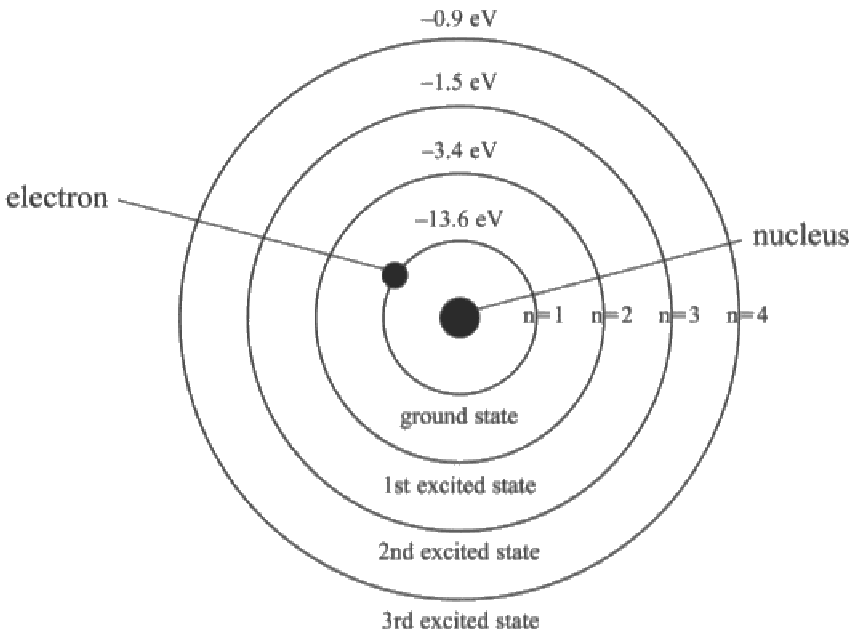
Examiner Comments

This does not gain credit as the answer must be in terms of energy. References to shells or orbitals are not accepted.

ResultsPlus
Examiner Tip

When discussing the arrangement of electrons in atoms in your Physics examinations you must refer to energy levels and not orbitals or shells.

15 In 1913 Niels Bohr proposed the model of the hydrogen atom represented in the diagram.



In this model an electron can orbit the nucleus at different energy levels, some of which are shown in the diagram.

(a) State what is meant by excited with reference to this model.

(1)

Jumping of electrons from ~~one energy level to the next~~.
ground state to first excited state.

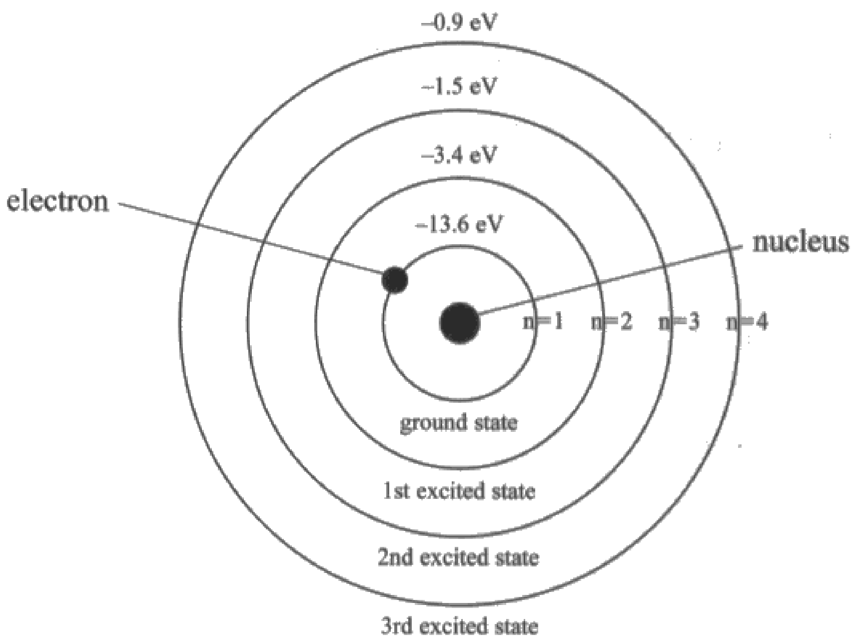
ResultsPlus
Examiner Comments

As the question asks for the meaning of 'excited', reference to 'excited state' alone will not be sufficient.

ResultsPlus
Examiner Tip

Definition of a term must be based on more than repetition of that term.

15 In 1913 Niels Bohr proposed the model of the hydrogen atom represented in the diagram.



In this model an electron can orbit the nucleus at different energy levels, some of which are shown in the diagram.

(a) State what is meant by excited with reference to this model.

(1)

move to higher or lower energy level.

ResultsPlus
Examiner Comments

This offers the examiner the choice between higher and lower and so does not get the mark. If a candidate isn't sure, they can't expect the examiner to choose for them. The exception would be when multiple answers are all acceptable individually.

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Examiner Tip

If you leave a choice of answers and one is incorrect, you will not be given the mark.

Question 15 (b)

A very large majority got at least half of this correct, and nearly half completed it fully. Errors encountered were choosing the wrong pair of levels, not converting from eV to J or not dividing by the Planck constant.

(b) Calculate the highest frequency of radiation that could be emitted by electrons involved in transitions between energy levels shown in the diagram.

(4)

$\Delta E = hf$

$\therefore f = \frac{\Delta E}{h}$

$= \frac{-0.9 - (-13.6)}{6.63 \times 10^{-34}}$

$= \frac{12.7}{6.63 \times 10^{-34}}$

$= 1.915 \times 10^{34}$ Hz

Frequency = ~~1.915 × 10^34^~~ 1.915×10^{34} Hz

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Examiner Comments

The correct energy levels have been chosen and an energy difference has been divided by the Planck constant for two marks, but the energy has not been converted from eV to J first. Candidates might be reminded of the need to do this by noticing the unit of the Planck constant, J s.

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Examiner Tip

Calculations for the photoelectric effect and atomic spectra may involve energy in eV or J and you need to check carefully whether a conversion is required.

(b) Calculate the highest frequency of radiation that could be emitted by electrons involved in transitions between energy levels shown in the diagram.

(4)

~~(−13.6)~~ (−3.4) − (−13.6) = 10.2 eV

= 10.2 × 1.60 × 10^{-19} = 1.6 × 10^{-18} ~~e~~V

E = hf

$f = \frac{E}{h} = \frac{1.6 \times 10^{-18}}{6.63 \times 10^{-34}} = 2.4 \times 10^{15}$ Hz

Frequency = 2.4 × 10^{15} Hz

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Examiner Comments

This answer uses the correct method to determine frequency, but the energy levels chosen do not correspond to the highest frequency of radiation, so just two method marks were awarded.

Question 16 (a)

While the mark for waves meeting was straightforward and usually awarded, the following part about adding displacement was only seen about a fifth of the time. There were often descriptions, sometimes with diagrams, of peaks and troughs meeting, showing that students had an understanding in outline, but they could not give this standard definition. Many students referred to adding amplitudes or mixed amplitude and displacement in their answers.

16 (a) State what is meant by the principle of superposition of waves.

(2)

When two crests ~~are~~ are moving in opposite directions and they meet constructive interference occurs. When a trough and crest meet ~~destr~~ (and they are travelling in opposite directions) destructive interference occurs.

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Examiner Comments

This gets credit for two or more waves meeting, but references to crests and troughs alone are not sufficient for the sum of displacements mark.

16 (a) State what is meant by the principle of superposition of waves.

(2)

~~When waves travel~~ When 2 progressive waves travel in opposite directions they superpose. ~~?~~ at points where the waves are in phase, the amplitude will increase, if they are in ~~antiphase~~ antiphase ~~the~~ the amplitude will decrease. Constructive and destructive interference occures, respectively.

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Examiner Comments

The reference to increasing or decreasing amplitude is not sufficient for the second mark. Candidates must refer to the addition of displacements.

Question 16 (b) (i)

About half of the entry gained at least half of the marks for this part, with about one in eight completing it for four marks. Those scoring two marks often got both of the marks for path difference or both of the marks for phase, often not discussing the other aspect.

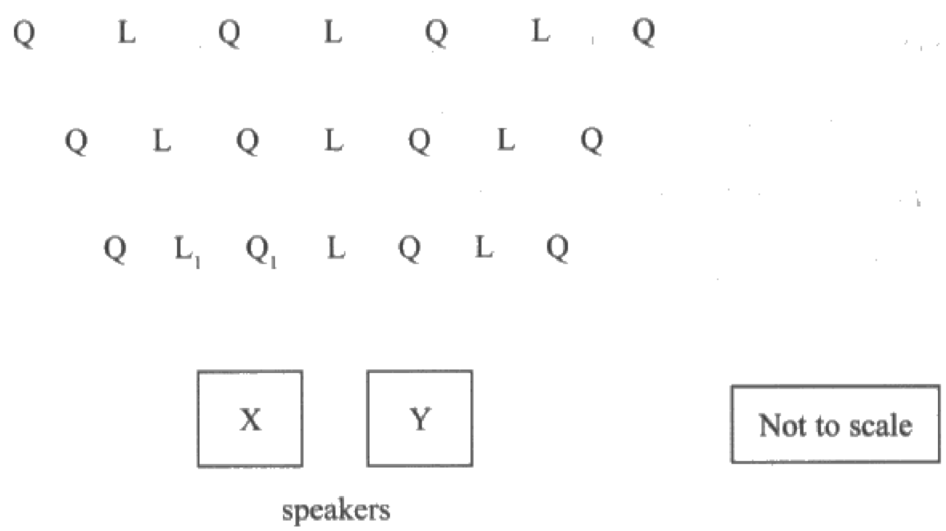
Many candidates calculated the path difference but did not relate it to wavelength correctly.

Some candidates lost a phase mark by referring to waves being 'out of phase', which is not specific enough, rather than 'antiphase'.

(b) A teacher demonstrating superposition set up two speakers in a laboratory. The students stood in different positions throughout the laboratory. The teacher played a single note through one of the speakers.

The teacher then played the note through both speakers and asked the students to describe their observations. Students in some positions said the sound got louder and students in other positions said the sound got quieter.

The students noted positions of louder sound L and quieter sound Q. Their results are shown in the diagram.



(i) The wavelength of the note was 0.8 m.
The following distances were measured:

X to L_1 = 1.6 m

Y to L_1 = 2.4 m

X to Q_1 = 1.7 m

Y to Q_1 = 2.1 m

Using the distances given, explain why the sound is loud at L_1 and quiet at Q_1.

(4)

The sound is loud at L1 because the waves from X and the waves from Y are in phase which will bring about constructive interferance making it louder. However the waves meeting at Q1 from X and Y are not in phase due to the path difference which brings upon the phase difference in the wave. This leads to a distructive interference because the waves are not in phase making the sound at Q1 sound quieter compared to L1.

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Examiner Comments

The candidate has not used the information on path length and wavelength to provide support for the statements about phase and may simply be repeating a standard explanation of interference.

Only one mark is awarded for the phase discussion because the destructive interference part only refers to 'not in phase' instead of 'antiphase'. 'Not in phase' refers to any difference that means they aren't in phase whereas 'antiphase' means exactly π out of phase.

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Examiner Tip

'Out of phase' simply means not in phase. The situation for destructive interference should be described as 'antiphase'.

(i) The wavelength of the note was 0.8 m.
The following distances were measured:

X to L_1 = 1.6 m

Y to L_1 = 2.4 m

X to Q_1 = 1.7 m

Y to Q_1 = 2.1 m

Using the distances given, explain why the sound is loud at L_1 and quiet at Q_1.

(4)

the path difference from x to L_1 and Y to L_1 is 2.4 - 1.6 = 0.8 this one λ and therefore forms a maxima there the path difference between x to Q_1 and Y to Q_1 = 2.1 - 1.7 = 0.4 this ½λ and therefore forms a minama
a maxima is where constructive inteference takes place and a loud sound is produced. therefore at L_1 the sound is loud. minima is where distructive inteference happens and quite or no sound is produced. therefore ~~there~~ it is quite at Q_1.

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Examiner Comments

The path differences have been determined and related correctly to wavelength for two marks but there is no discussion of phase relationships for further marks.

Question 16 (b) (ii)

Half of the candidates gained a mark, usually for suggesting varying frequency or wavelength. Some discussed varying amplitude at the source, but this wouldn't prevent the effect. Others simply talked about changing notes or pitch, which was not sufficient for frequency. Candidates did not often successfully describe the result of the varying wavelength, often effectively repeating part of the question as a conclusion.

(ii) Explain why this pattern is **not** observed when the speakers are playing music.

(2)

Music has different notes ~~that~~ therefore the wavelength will keep on changing, so a pattern cannot be observed.

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Examiner Comments

The changing wavelength is correctly identified, but there is no further detail on how this affects the pattern. Repeating the question is not sufficient.

(ii) Explain why this pattern is **not** observed when the speakers are playing music.

(2)

The phase relationship would not be constant, so any interference pattern would ~~fat~~ fluctuate too quickly for us (humans) to notice.

ResultsPlus

Examiner Tip

This correctly states that the phase relationship would not be constant, but does not say why in terms of changing frequencies or wavelengths.

Question 17 (a)

As in previous years, candidates showed that they know a lot of facts about the photoelectric effect and they often wrote down as many of them as they could. What they did not always do was to select the appropriate information for this particular context. The question stated that intensity was decreased and asked about consequent changes, but many students discussed the effect of changing frequency on maximum kinetic energy. As neither of these actually changed they were not relevant in this case.

Overall, a majority got at least one mark for stating that the rate of electron emission decreased. About a half of these successfully explained this in terms of photons or waves, but few explained it in terms of both. A lot discussed what would not happen instead.

17*(a) A metal surface is illuminated with light of a single frequency. This frequency is above the threshold frequency of the metal and so electrons are emitted. The rate of electron emission is measured.

The intensity of the incident light is then decreased but its frequency remains unchanged.

Describe the change in electron emission that would be observed and how this change would be explained by the wave theory and by the particle theory of light.

(3)

The number of electrons emitted ~~would~~ ~~d~~ per unit time would decrease but the kinetic energy will remain constant. $E=hf$ and energy depend on frequency. according to the wave theory the energy of the wave increases when intensity increases therefore the kinetic energy of electrons emitted should decrease when the intesity is decreased but that doesn't happen.

ResultsPlus
Examiner Comments

This response correctly states that the rate of emission of electrons would decrease. It then goes on to explain in further detail the effect on kinetic energy. This is something that does not change but the question asks for an explanation of the change, so it is not relevant.

17*(a) A metal surface is illuminated with light of a single frequency. This frequency is above the threshold frequency of the metal and so electrons are emitted. The rate of electron emission is measured.

The intensity of the incident light is then decreased but its frequency remains unchanged.

Describe the change in electron emission that would be observed and how this change would be explained by the wave theory and by the particle theory of light.

(3)

E=hf. one photon release one electron. Emission of electrons is instantaneous. Number of electrons depend on intensity, not depends on frequency. The maximum energy for electrons to emit depends on frequency, not depends on intensity. There is no a cumulation for electrons to emit. Wave energy should build up. wave energy depends on intensity. More intense light will give more kinetic energy. So, when the intensity decreased, the number of electrons decrease. ~~When~~ But the frequency remains constant. so the KE for electrons is constant.

ResultsPlus
Examiner Comments

This answer reads as if the candidate has written all that could be remembered about photoemission hoping that something will be correct. There is one mark for 'the number of electrons decrease'. Much of the rest of the discussion is about frequency, which isn't part of the question, and kinetic energy, which does not change and so is not part of the answer to this question about changes.

ResultsPlus
Examiner Tip

The photoelectric effect has many different aspects so, when answering questions on this effect, read the question carefully and only discuss the aspects being asked for.

Question 17 (b)

A large majority completed this unusual but relatively simple calculation, although some added the maximum kinetic energy instead of subtracting it from the photon energy.

(b) Light of frequency 7.3×10^{14} Hz is incident on the surface of the metal. The maximum kinetic energy observed for emitted electrons is 1.8×10^{-19} J.

Calculate the work function energy for the metal in J.

(2)

$hf = W_0 + \frac{1}{2}mv^2$

$hf - \frac{1}{2}mv^2 = W_0$

$W_0 = (6.63 \times 10^{-34} \times 7.3 \times 10^{14}) - 1.8 \times 10^{-19}$

Work function energy = 4.84×10^{-19} J

ResultsPlus
Examiner Comments

This is set out correctly for one mark, but the final calculation has not been completed as the kinetic energy has not been subtracted.

(b) Light of frequency 7.3×10^{14} Hz is incident on the surface of the metal. The maximum kinetic energy observed for emitted electrons is 1.8×10^{-19} J.

Calculate the work function energy for the metal in J.

(2)

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

$6.63 \times 10^{-34} \times 7.3 \times 10^{14} = \Phi + 1.8 \times 10^{-19}$

$\Phi = \frac{6.63 \times 10^{-34} \times 7.3 \times 10^{14}}{1.8 \times 10^{-19}}$

Work function energy = 2.69 J

ResultsPlus
Examiner Comments

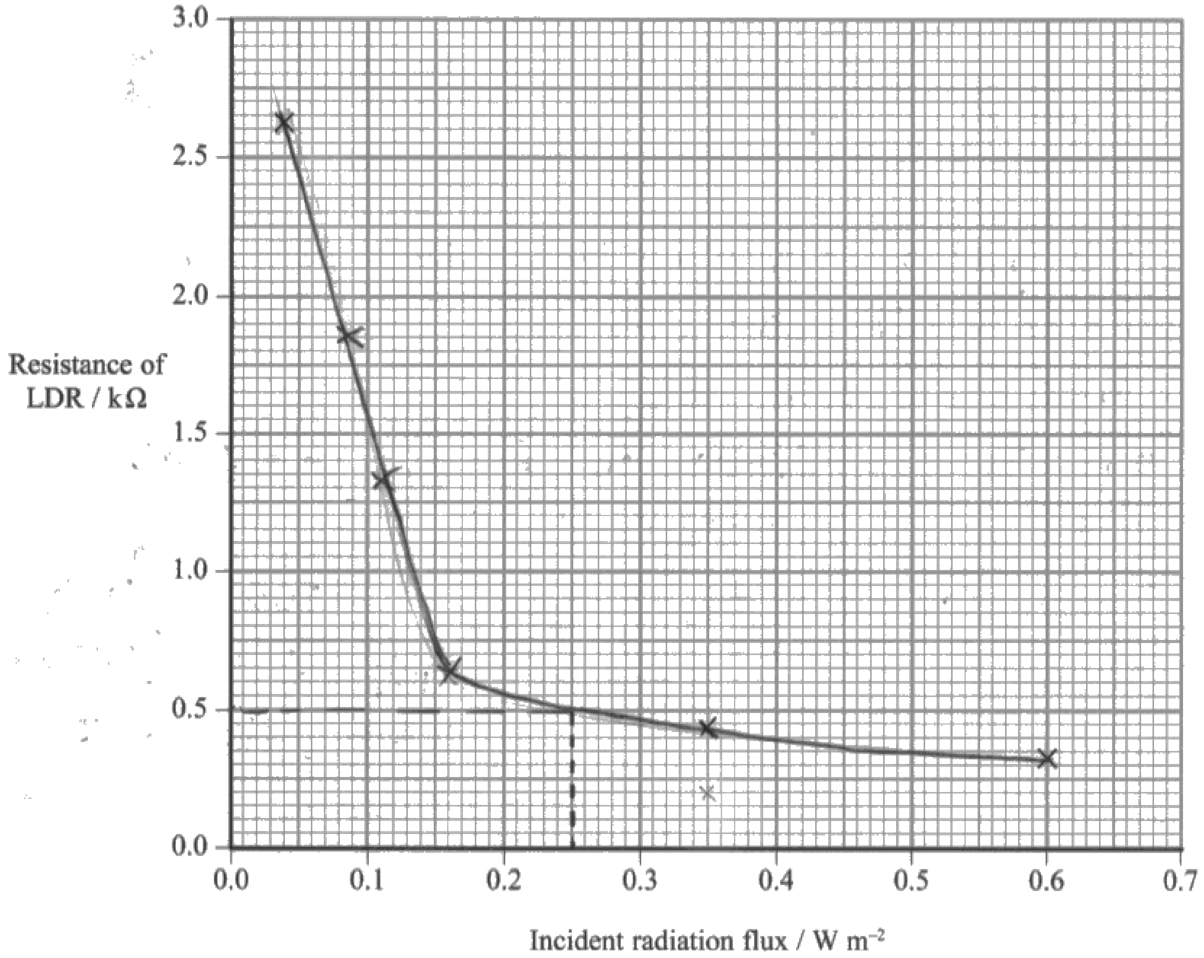
This also has been set out correctly for one mark but the final operation of subtraction has been replaced by division.

Question 18 (a)

A large majority got at least two marks, but just under half of candidates got no marks for the graph through a mixture of plotting errors and curves that were not judged to be the best fit. The mark scheme shows acceptable lines.

(a) Use the results in the table to complete the graph.

(3)



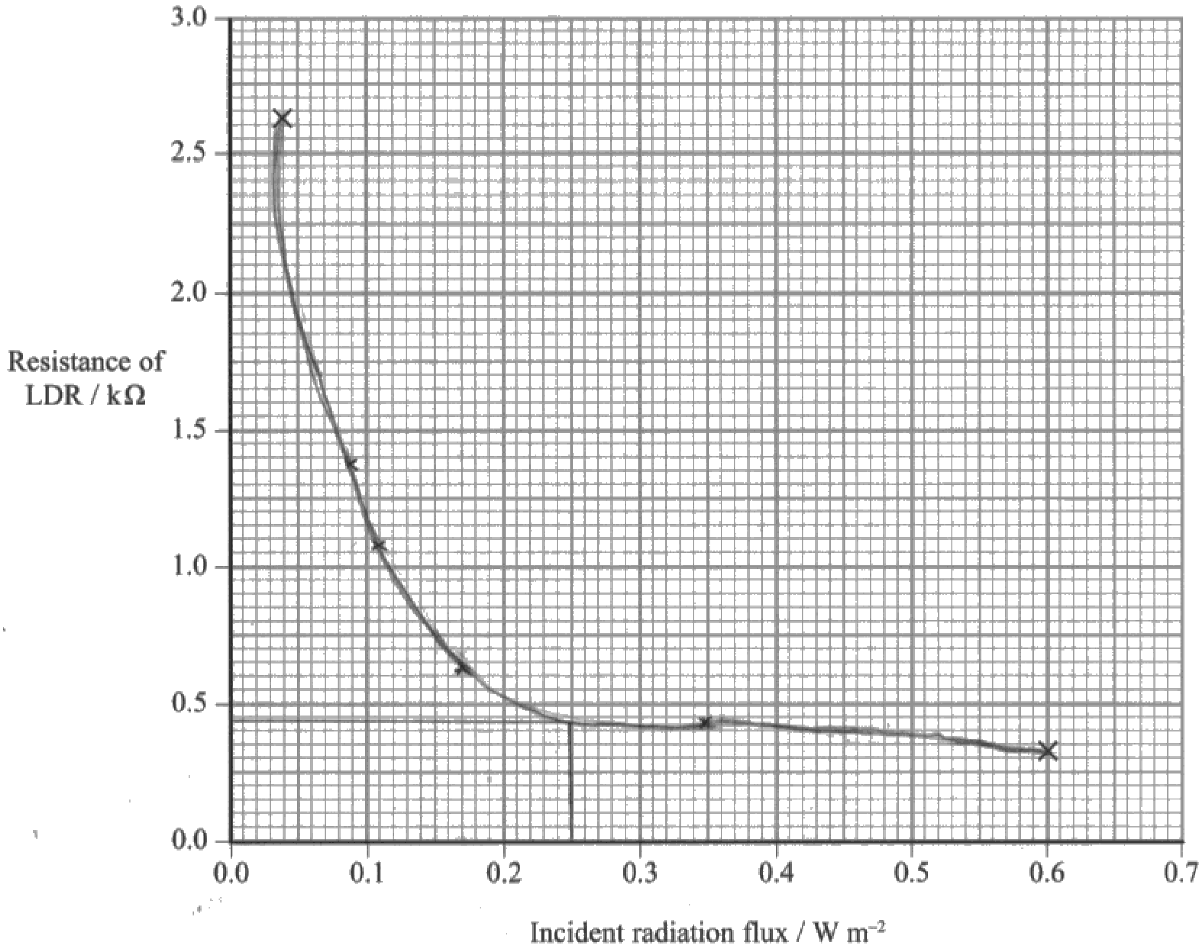
ResultsPlus

Examiner Comments

Completed graphs rarely get no marks at all, but this has too many incorrect points and the marked elbow in the curve means that it is not sufficiently smooth for credit.

(a) Use the results in the table to complete the graph.

(3)



ResultsPlus

Examiner Comments

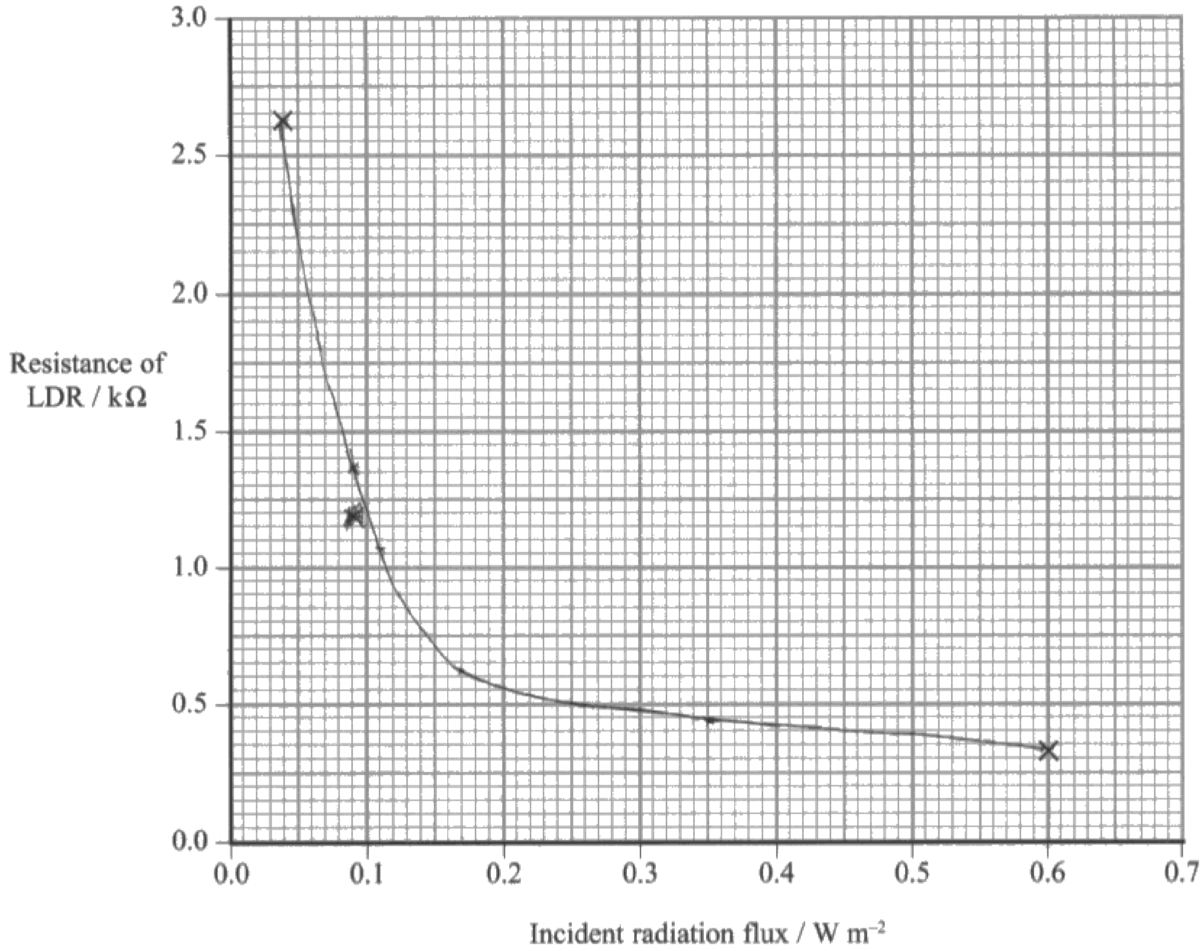
The plots are correct but there is an inexplicable change in direction at the start and a bump at the fifth point.

Question 18 (b)

While well over half of the candidates read the value from the graph correctly, only about half of them used it successfully to determine the required resistance. The potential divider method using ratios was generally more successfully completed, but it was applied less often than the alternative method of calculating the current through the LDR and using this for the resistance. An error in the second method was to apply the incorrect potential difference for the resistor. A minority of candidates read from the graph as Ω rather than kΩ.

(a) Use the results in the table to complete the graph.

(3)



(b) The lighting circuit will switch on when the potential difference across XY is 0.60 V.

Determine the required resistance R of the variable resistor so that the lighting circuit will switch on when the incident radiation flux is 0.25 W m^{-2}.

(3)

From the graph, at 0.25 Wm^{-2}, the resistance of LDR is 0.5 k Ω.

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

$I = \frac{0.6}{0.5 \times 1000}$

$= 1.2 \times 10^{-3}$ A.

The required resistance R of the variable resistor $= \frac{V}{I}$

$= \frac{0.6}{1.2 \times 10^{-3}}$

~~= 5 k Ω~~

= 5000 Ω = 5 k Ω

Resistance = 5 k Ω

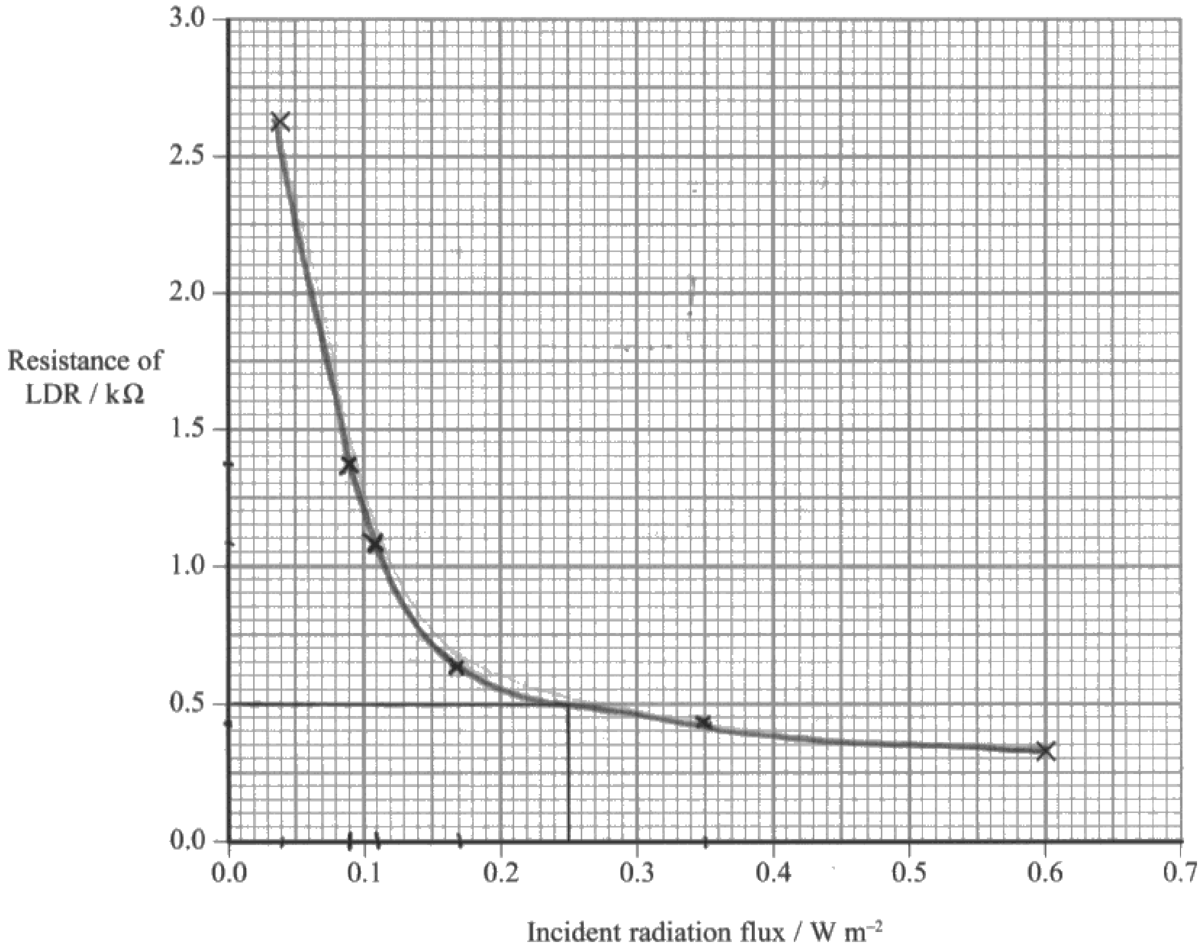
ResultsPlus

Examiner Comments

This adopts a correct overall method, but the resistance calculated as the 'required resistance' is actually the total resistance of the variable resistor and the LDR. The p.d. used should have been 5.4 V, or 500 Ω should have been subtracted from the answer given.

(a) Use the results in the table to complete the graph.

(3)



(b) The lighting circuit will switch on when the potential difference across XY is 0.60 V.

Determine the required resistance R of the variable resistor so that the lighting circuit will switch on when the incident radiation flux is 0.25 W m^{-2}.

(3)

6V = power pack supply

$V_{xy} = \left(\frac{0.5}{0.5 + R_{\text{variable resistor}}}\right) 6V$

$V_{xy} = 0.6$ $\quad 0.1 = \frac{0.5}{0.5+R}$

$0.05 + 0.1R = 0.5$

$0.1R = 0.45$

$R = 4.5$

check
(4.5):(0.5)
6
$\frac{6}{10} = 0.6$ ✓

Resistance = 4.5 Ω

ResultsPlus
Examiner Comments

This has been completed correctly through all the stages of calculation, but the graph axis has not been read carefully enough and the units have been given as Ω rather than kΩ.

Question 18 (c)

About half of the candidates scored on this question, usually for more readings, but only about a third of them got both marks by linking more readings to an improvement in the graph. A lot made unsupported statements about improved accuracy or avoiding parallax errors, although these would be the same as with a student taking measurements from a digital meter. Some said it would be easier, which does not improve the quality.

(c) Apart from eliminating human error, suggest how using a resistance sensor and a radiation flux sensor connected to a data logger could have improved the quality of the graph.

(2)

More readings can be obtained. The reading of incident radiation flux and resistance of LDR can be read at the ~~same~~ same time.

ResultsPlus
Examiner Comments

More readings is an acceptable improvement in the technique, but it has not been related to the improvements in the graph as asked for in the question.

(c) Apart from eliminating human error, suggest how using a resistance sensor and a radiation flux sensor connected to a data logger could have improved the quality of the graph.

(2)

when using these apparatus there will be no reaction time and donot have to measure the readings simultaneously.
Automatically a graph can be plotted

ResultsPlus
Examiner Comments

This correctly identifies an advantage with respect to graph plotting for one mark. Reaction time and simultaneous readings are not relevant in this case because there is not a rapidly changing variable.

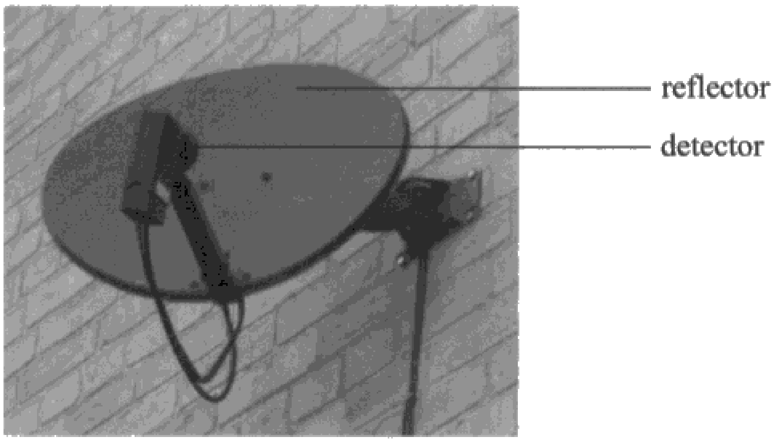
ResultsPlus
Examiner Tip

When describing improvements in experimental techniques, be sure they are relevant to the practical work being discussed.

Question 19 (a) (i)

Although most candidates were able to apply the wave equation, about a third did not get the final answer, usually through a power of ten error for Giga. A surprising number only gave the answer as 2 cm and did not include the required extra significant figure for 'show that' questions.

19 The photograph shows a satellite television dish.



Electromagnetic radiation from a communications satellite is reflected from the reflector to the detector.

(a) The radiation used has a frequency of 12.6 GHz.

(i) Show that the wavelength of the radiation is about 2 cm.

(2)

$v = f\lambda$

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

$= \frac{3\times10^6}{12.6\times10^9}$

$= 0.02\,m$

$\approx 2\,cm$ # (shown)

ResultsPlus
Examiner Comments

This has been calculated correctly, but the answer has only been quoted to one significant figure, which is the same as the 'show that' value, and not to the required extra significant figure.

ResultsPlus
Examiner Tip

In a 'show that' question, your answer must be given to one significant figure more than the value in the question. This shows that you have calculated it and not just copied it.

19 The photograph shows a satellite television dish.

Electromagnetic radiation from a communications satellite is reflected from the reflector to the detector.

(a) The radiation used has a frequency of 12.6 GHz.

(i) Show that the wavelength of the radiation is about 2 cm.

(2)

$f = \frac{c}{\lambda}$ $\qquad \frac{3.0\times10^8}{12.6\times10^7} = \lambda$

$12.6\times10^6 = \frac{3.0\times10^8}{\lambda}$ $\qquad \lambda = 2.3$ cm

ResultsPlus
Examiner Comments

This gets a mark for applying the wave equation, but Giga has been incorrectly applied as 10^6 and as 10^7. The numerical value 2.38 has been truncated to 2.3 instead of being rounded to 2.4.

ResultsPlus
Examiner Tip

Be sure to know the required SI prefixes.

Question 19 (a) (ii)

About three quarters gave the correct region of the electromagnetic spectrum. Those who have carried out microwave experiments may find this easier to remember.

(ii) State the region of the electromagnetic spectrum to which this radiation belongs.

(1)

Visible light

ResultsPlus
Examiner Comments

This is incorrect and is a surprising choice because it should be plain that there is no extra illumination from the satellite.

(ii) State the region of the electromagnetic spectrum to which this radiation belongs.

(1)

below visible light

ResultsPlus
Examiner Comments

It is not clear what is meant by below, but even if taken as frequency this is not precise enough. In effect, this candidate has just made one suggestion for a type of radiaition rather than making a suggestion as to what it is.

Question 19 (b)

Most candidates applied the equation correctly and over two thirds arrived at the correct answer for two marks. Slips along the way included using 10^{-3} or 10^{13} and some omitted the unit or gave it as J.

(b) The radiation incident on the reflector has a radiation flux of 4.8×10^{-13} W m^{-2}.

Calculate the power of the incident radiation.

area of the reflector = 0.27 m^2

(2)

~~4.8 ×~~ $F = \frac{P}{A}$

$(4.8 \times 10^{-13}) = \frac{P}{0.27}$

$P = 1.296 \times 10^{-13}$

$\simeq 1.3 \times 10^{-13}$ J

Power = 1.3×10^{-13} J

ResultsPlus

Examiner Comments

This calculation is correct but the final unit has been given as J rather than W and therefore the final mark for the answer is not awarded because magnitude cannot be expressed correctly without the correct unit.

ResultsPlus

Examiner Tip

Numerical answers must include a correct unit to be awarded the answer mark.

Quantities not requiring a unit are those expressed as ratios, such as efficiency, refractive index and sine.

(b) The radiation incident on the reflector has a radiation flux of 4.8×10^{-13} W m^{-2}.

Calculate the power of the incident radiation.

area of the reflector = 0.27 m^2

(2)

~~Φ~~ A = ~~Φ~~P / 12

0.27 = P / 4.8×10^{-3} ~~P = 4.8×10^{-3} W~~

P = 1.296 × 10^{-3}

Power = ~~4~~ 1.296×10^{-3}

ResultsPlus

Examiner Comments

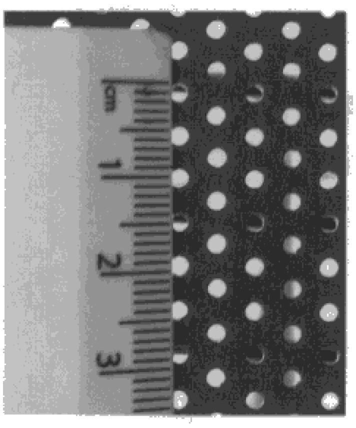
The method used here is correct, but the radiation flux value has been copied incorrectly, so the final answer is incorrect. This candidate has omitted the unit entirely.

Question 19 (c) (i)

Just over two thirds got this correct. Some lost the mark through trying to quote the answer in m or in standard form and making errors in converting from 2 mm.

(c) The reflector contains many small holes.

(i) Use the photograph to estimate the diameter of the holes.



(1)

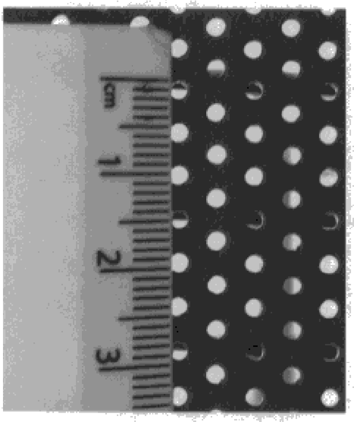
2 mm = diameder of the holes = 0.002 m

ResultsPlus
Examiner Comments

This answer has been quoted in mm and m. Both are correct but repeating makes it more likely that an error will be made, so it is best to give only one answer.

(c) The reflector contains many small holes.

(i) Use the photograph to estimate the diameter of the holes.



(1)

0.2 cm = 2×10^{-3} m.

ResultsPlus
Examiner Comments

This is another example of the answer being given in different units, here cm and m. As before, 0.2 cm was fine and there was a chance of error being introduced with the conversion.

Question 19 (c) (ii)

Only about one in ten scored even one mark here. Many made it clear that they think that diffraction only occurs when the wavelength is about the same as the gap size. Many more have apparently only considered diffraction when gap size is equal to or greater than wavelength and not investigated smaller gaps where there is still diffraction through a very large angle but a decreasing intensity.

(ii) It is important that the radiation is reflected to the detector with the maximum possible power.

Use the idea of diffraction effects to explain why the radiation is reflected as if from solid metal.

(2)

Diffraction - spreading out of a wave - only occurs if the wavelength of a wave is similar to the slits in its size. Here, wavelength is much greater than the diameter of the holes, so no diffraction takes place.

ResultsPlus
Examiner Comments

This incorrectly suggests that diffraction only occurs when the size of the gap is the same as the wavelength and concludes that there is no diffraction at all because of the difference in size between wavelength and gap size.

ResultsPlus
Examiner Tip

You must be able to describe the effects of diffraction when the gap is much smaller than the wavelength as well as when it is much larger and when the sizes are similar.

(ii) It is important that the radiation is reflected to the detector with the maximum possible power.

Use the idea of diffraction effects to explain why the radiation is reflected as if from solid metal.

(2)

Diffraction is the spreading of waves at reaching obstacles. Maximum diffraction occurs when the ~~spac~~ spacing of gaps is similar to the wavelength of the incident wave. In this case the gap spacing is much less than the wavelength (0.18 << 2.38) so almost no diffraction occurs, reflection instead.

ResultsPlus

Examiner Comments

This response shows a better appreciation of the link between gap size and diffraction, but there is still ambiguity and it is not clear whether 'almost no diffraction' applies to the angle of diffraction or to the intensity of the diffracted wave.

Question 19 (c) (iii)

Under a tenth of the entry made a successful suggestion. Many linked it to changes in absorption of microwaves, and a lot said it would be useful to increase diffraction of the waves.

(iii) Suggest a reason for having holes in the reflector, rather than using solid metal.

(1)

~~Allows for diffraction – [illegible] waves will~~

During times of rain, the water would not collect on the reflector and seep down, allowing effective reflection.

ResultsPlus

Examiner Comments

This is one of the more sensible suggestions made by candidates.

(iii) Suggest a reason for having holes in the reflector, rather than using solid metal.

(1)

Reduces the cost of the reflector as less metal is required to build it.

ResultsPlus

Examiner Comments

This is another sensible suggestion.

Question 20 (a) (i)

About a sixth of candidates gained a mark for this question, usually for stating that there would be a large percentage uncertainty. Many candidates just said that it would not be accurate or said that there would be errors without relating them to percentage uncertainty and a lot of students thought the method was satisfactory. A substantial minority focused on possible improvements, but that was not the question.

Comment on the use of this method to measure the width of the metal strip.

(2)

The ~~Scale~~ scale is too large to ~~read the~~ read the ~~text~~ width of metal strip, therefore the reading will be inaccurate.

ResultsPlus
Examiner Comments

There is some appreciation of the situation, but insufficient detail is given of the effect on the measurement.

Comment on the use of this method to measure the width of the metal strip.

(2)

The Student should use ~~verner~~ vernier calipor instead of meter rule to make measurements more accurate. Take reading at different place of insulating material and ~~to~~ average.

ResultsPlus
Examiner Comments

This student is answering a different question - perhaps 'describe how to improve this measurement'. It may have loooked like a question on a previous paper, but the candidate has been asked to comment on the method used rather than suggest improvements.

ResultsPlus
Examiner Tip

A question may look like one you have seen before, but you should read every question carefully to be sure you answer what it actually asks you to.

Question 20 (a) (ii)

Two thirds could apply the equation, but the area used was not always correct. Some students decided that they were dealing with a wire and used π*r*².

A minority could not rearrange the resistivity equation correctly.

Calculate the resistivity of the metal in Ω m.

(2)

Area = Width × thickness = 1.5 × 0.24 = 0.36 mm²

$= \frac{0.36}{1000} = 3.6 \times 10^{-4}$ m² $\rho = \frac{RA}{L}$

$= \frac{1.8 \times 3.6 \times 10^{-4}}{0.485}$

length $= \frac{48.5}{100} =$ 0.485 m

$= 1.3 \times 10^{-3}$ Ω m

Resistivity = 1.3×10^{-3} Ω m

ResultsPlus
Examiner Comments

The overall method is correct here, but there has been an error in the conversion of mm² to m². In this case it would have been better to convert the lengths from mm to m before calculating the area.

ResultsPlus
Examiner Tip

Remember that 1 m² is (1000 mm)², i.e. 1 x 10⁶ mm².

It is usually better to do unit conversion before any further processing of data, i.e. to convert lengths before calculating areas or volumes.

Calculate the resistivity of the metal in Ω m.

(2)

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

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

$\rho = \frac{1.8 \times \pi \times (1.2 \times 10^{-4})^2}{0.485}$

$\rho = 1.68 \times 10^{-7}\ \Omega m$

~~$\rho = 6.72 \times 10^{-6}\ \Omega m$~~

$1.68 \times 10^{-7}\ \Omega m$

Resistivity = ~~6.72×10^{-6}~~ Ω m

ResultsPlus

Examiner Comments

Some candidates, as here, assumed the cross-section was circular and used the thickness as the diameter. Apart from that, the method is correct and one mark was awarded.

Question 20 (b)

This was answered successfully by about four fifths of candidates with a few transcription errors, like 320 V, and missing units costing some students a mark.

Calculate the total resistance of the metal strips in the toaster.

(2)

~~St~~ Number of strips = 11

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

$\therefore R = \frac{V^2}{P} = \frac{(230)^2}{1400} = 37.8\,\Omega \times 11 = 415.6\,\Omega$

Total resistance = 415.6 Ω

ResultsPlus
Examiner Comments

This example shows the correct method to find the total resistance, but there is a slight misunderstanding of the situation and the candidate thought this was just for one strip and went on to multiply by 11.

Calculate the total resistance of the metal strips in the toaster.

(2)

~~P = VI~~ P = V² / R

~~1400 = 230 × I~~ 1400 = 230² / R

R = 37.8 Ωm

Total resistance = 37.8

ResultsPlus
Examiner Comments

The correct method has been used in this response, but the unit stated is incorrect.

Question 20 (c)

This is a standard description, commonly also met in relation to filament lamps, but only a third of candidates were able to score on this question, frequently just for linking increased lattice vibrations to increased collisions. Some lost a mark by referring to collisions between electrons only. Others linked increased thermal energy to increased drift velocity of electrons. Very few linked a change in drift velocity to a change in current and therefore resistance. Many just left it that more collisions result in more resistance without further expansion on why this should be. This was sometimes related to a friction idea.

(c) Explain why the resistance of the metal strips in the toaster increases as the temperature increases.

(3)

As the temperature increases the electrons gain energy and the drift velocity increases. The electrons will collide more with the lattice ions. There will be less charge per carrier.

ResultsPlus
Examiner Comments

This answer states that there will be more collisions of electrons with lattice ions, but the reason is incorrect. The increase in thermal energy has been linked to an increase in drift velocity rather than an increase in vibration of the lattice ions and a decrease in drift velocity.

(c) Explain why the resistance of the metal strips in the toaster increases as the temperature increases.

(3)

As temperature increase metal atoms gain kinetic energy and vibrate faster. Due to this increased vibration ~~there~~ they collide more charge carrying electrons and they stop them from moving so higher resistance.

ResultsPlus
Examiner Comments

This has a correct description of increased collisions and the reason, but goes too far in suggesting that this stops movement of the electrons, giving this as the cause of greater resistance.

(c) Explain why the resistance of the metal strips in the toaster increases as the temperature increases.

(3)

A temp. increase would mean the metal ions are vibrating faster, and with greater amplitude. This would result in increased collisions, so "v" decreases. $I = nvqA$. Decrease of "v" means a decrease in "I", $V/I = R$. A ~~decrease~~ decrease in "I", ~~[illegible]~~ means "R" would have increased. ~~[illegible]~~

ResultsPlus

Examiner Comments

This nearly got full marks. It has the correct change in drift velocity and completes the argument by linking this to reduced current and therefore increased resistance using $R = V/I$. There is just one detail missing, which is the nature of the collisions.

Question 21 (a)

This was very well answered with few errors. The most common cause of a loss of marks was giving the answer as 2.4 without the extra significant figure required in a 'show that' question.

Show that the refractive index of diamond is about 2.4.

speed of light in diamond = 1.24×10^8 m s^{-1}

(2)

$$_a\mu_{diamond} = \frac{v_1}{v_2}$$

$$= \frac{3 \times 10^8}{1.24 \times 10^8}$$

$$= 2.4$$

ResultsPlus

Examiner Comments

The method and answer are correct, but the answer is only quoted to 2 significant figures, as the quoted 'show that' value, and not to the required extra significant figure.

ResultsPlus

Examiner Tip

In a 'show that' question, your answer must be given to one significant figure more than the value in the question. This shows that you have calculated it and not just copied it.

Show that the refractive index of diamond is about 2.4.

speed of light in diamond = 1.24×10^8 m s^{-1}

(2)

$$\text{refractive index} = \frac{\text{speed of light in vacuum}}{\text{speed of light in diamond}} \Rightarrow \frac{3\times10^8}{1.24\times10^8} = 2.419.... \simeq 2.4$$

ResultsPlus

Examiner Comments

This is an example of a fully correct answer with the extra significant figures.

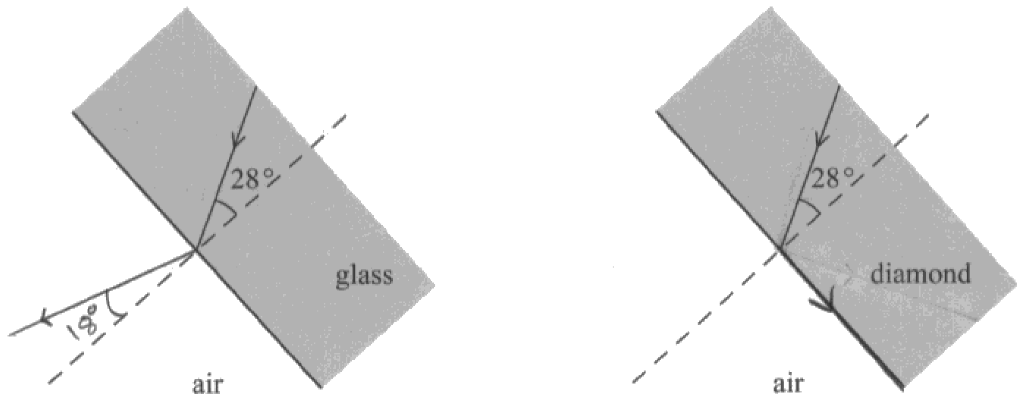
Question 21 (b)

The great majority scored on this question, with over half gaining at least 2 marks and about a quarter getting 5 or more.

A common error was to apply Snell's law equation, treating the angle of incidence in the solid as the angle in the less dense medium, i.e. as *i* in sin *i* / sin *r*. Candidates who got the correct angle frequently did not add to the diagram. Candidates calculating the critical angles were usually successful, but they did not always explain the consequence in terms of whether total internal reflection occurred and did not always add to the diagram.

(b) Imitation gemstones can be made from glass.

The diagrams show incident light at a boundary of glass with air and at a boundary of diamond with air. The angle of incidence is 28° in each case.



Use appropriate calculations to determine what happens to the light in each case and complete the diagrams to show this, labelling the relevant angles.

refractive index of glass = 1.50

(6)

* Glass) $1.5 = \frac{\sin(28)}{\sin(r)}$, $r = 18.2°$

* Diamond) $2.42 = \frac{1}{\sin C}$ $C = 24.4°$

=> (i) angle is greater than critical angle so total internal reflection occurs

ResultsPlus

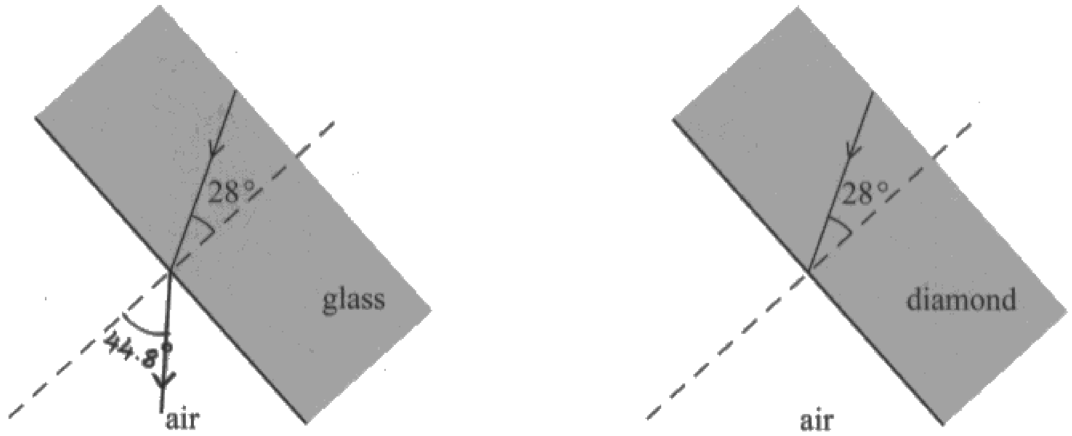
Examiner Comments

For diamond the calculation is correct, as is the conclusion that total internal reflection occurs, but the ray has been drawn as for the critical angle and not total internal reflection.

The common error has been made for glass, treating the angle of incidence in glass as the angle in the less dense medium. A ray has been added to the diagram, but it is on the wrong side of the normal, as if there is some reflection.

(b) Imitation gemstones can be made from glass.

The diagrams show incident light at a boundary of glass with air and at a boundary of diamond with air. The angle of incidence is 28° in each case.



Use appropriate calculations to determine what happens to the light in each case and complete the diagrams to show this, labelling the relevant angles.

refractive index of glass = 1.50

(6)

For glass

$\frac{\sin i}{\sin 28} = \frac{1.50}{1}$

$\sin i = 0.7042...$

$i = 44.8°$

for diamond

$\frac{\sin i}{\sin 28} = \frac{2.4}{1}$

i = no solution

∴ light reflects from the boundary

ResultsPlus
Examiner Comments

The calculation and diagram are correct for glass. The attempt to find an angle in air and the consclusion that there is no solution is correct, but the further conclusion is only that light reflects and not that there is total internal reflection. The ray has not been added to the diagram.

Question 21 (c)

Just over a fifth of candidates scored on this question by comparing the critical angles for glass and diamond. They often had some idea of the effect on reflection, but rarely expressed it in the required detail for the second mark, generally stating that more light would be reflected but not linking it to angles of incidence. As the critical angle affects which angles of incidence will result in total internal reflection, such a reference was required for the mark.

(c) Suggest why diamonds sparkle more than imitations made from glass.

(2)

- Diamonds has lower critial angle compare to imitations
- More light entering the diamond can reflect out .

ResultsPlus

Examiner Comments

This candidate has highlighted the difference in critical angle and stated that more light will be reflected, but no link has been made between the statements.

(c) Suggest why diamonds sparkle more than imitations made from glass.

(2)

Diamonds have a lower critic~~a~~al angle than glass and so ~~Sma~~ rays with smaller incident rays can total internal reflect.

ResultsPlus

Examiner Comments

This answer is closer to the second mark, but has been poorly expressed so it refers to smaller incident rays rather than smaller angles of incidence.

Paper Summary

Based on their performance on this paper, candidates should:

- Learn definitions in detail so they can be quoted fully, using the required terminology,
- Check that their quantitative answers represent sensible values and check their calculations when they do not,
- Earn standard descriptions of physical processes, such as the photoelectric effect, and be able apply them to specific situations, identifying the parts of the general explanation required to answer the particular question.

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

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