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June 2019

GCE Physics 9PH0 02

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Introduction

This was the third sitting of this examination for the new specification. The assessment structure of paper 2 is the same as that of paper 1, consisting of ten multiple choice questions and a number of short answer questions followed by longer, structured questions based on contexts of varying familiarity.

This specification has introduced two new question styles which were represented in this paper. Q13 assessed candidates' ability to structure answers logically while Q11, Q15(c), Q16(b)(i) and Q17(b)(ii) targeted assessment objective 3 (AO3). Of these, Q15(c) required the evaluation of scientific information, ideas and evidence and the other AO3 questions required a deduction or judgement along with a justified conclusion. Candidates generally answered these questions well, showing some ingenuity in the variety of approaches; although the conclusions were not always made sufficiently explicit for the numerical questions and so this meant that the final mark was not always awarded.

This 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.

Less successful candidates could complete calculations involving simple substitution and limited rearrangement, including a structured series of calculations, but could not always tackle calculations involving several steps or other complications, such as converting years to seconds. These candidates also provided some significant explanatory points linked to standard situations, such as the formation of emission spectra and the use of Doppler shift in the determination of relative velocity. However, they frequently 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. Overall these candidates scored much more highly on assessment objective 1 than on assessment objectives 2 and 3.

The most successful candidates completed calculations faultlessly and responded with explanatory points that were ordered logically and were relevant to the context of the question.

The multiple choice questions discriminated well, with overall performance improving across the ability range. Candidates around the E grade boundary typically scored about 3 or 4 and A grade candidates usually got 6 or 7 correct.

More details on the rationale behind the incorrect answers for each multiple choice question can be found in the published mark scheme.

Question 11

Most candidates made a good start to the question, applying the formulae $\Delta Q = mc\Delta\theta$, $\Delta Q = L\Delta m$ and $P = E/t$, with two thirds scoring 3 or more marks. Candidates sometimes went astray by using an incorrect mass of the wet handkerchief, but usually in $\Delta Q = mc\Delta\theta$ rather than in $\Delta Q = L\Delta m$, where Δm prompted them to look for a difference in mass. Some neglected to include latent heat or only considered latent heat, and others occasionally used the stated temperature rather than the temperature change. A significant proportion of those who completed all of the calculations correctly were not awarded the final mark because they did not make an explicit comparison of the values for the water and the iron, whether for total energy transferred or power, as part of a clear conclusion.

11 A wet handkerchief is dried in 56 s using a hot iron rated at 2400 W.

Determine whether energy is transferred to the water in the handkerchief at a greater rate than it is transferred to the iron.

initial temperature of wet handkerchief = 18 °C

initial mass of wet handkerchief = 35.9 g

final mass of dry handkerchief = 18.2 g

specific heat capacity of water = 4.19×10^3 J kg^{-1} K^{-1}

specific latent heat of vaporisation of water = 2.26×10^6 J kg^{-1}

(5)

$q = mc\Delta T$ $\quad$ $35.9 - 18.2 = 17.7$ g

$\Delta E = L\Delta m$ $\quad$ $2.26\times10^6 \times$ ~~0.177×10⁻³~~ = ~~40002~~

~~4.19×10³ = 91,164,400,000~~

$0.17.7\times10^{-3} = 40002$

$40,002 \div 56 = 714.32$ W

ResultsPlus Examiner Comments

This candidate is awarded 2 marks.

In this response, the formula for latent heat has been applied for the correct mass as well as the power calculated for this quantity. Specific heat capacity has not been used and there is no attempt at a conclusion.

~~$P = \frac{W}{t} = \frac{2400W}{56}$ A 42.857~~

$T_v = 100°C$ (all evaporates) $\Delta m = 35.9 - 18.2$

$100 - 18 = 82°C = 82K$ $= 17.7$

$\Delta E = mc\Delta\theta = 0.0359 \times 4.19 \times 10^3 \times 82 = 12334.522J$

$\Delta E = L\Delta M = 2.26 \times 10^6 \times 0.0177 = 40002.000J$

Total $\Delta E = 5\,2336.522J$

$P = E/t = 52336.522 \div 56 = 934.6W$

$934.6W < 2400W$

So energy is transferred at a greater rate to the iron

(Total for Question 11 = 5 marks)

ResultsPlus
Examiner Comments

This candidate has been awarded 4 marks.

The correct formulae have been applied, obtaining the 4 marks, but the wrong mass has been used with specific heat capacity.

The conclusion has been done correctly, but the correct answer is required for this final mark.

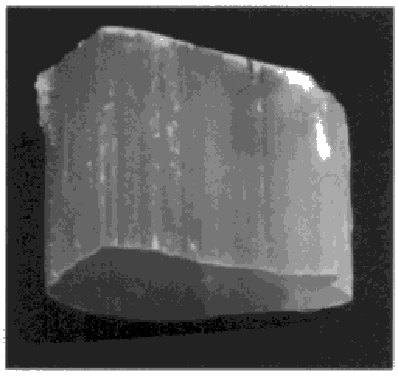
ResultsPlus
Examiner Tip

Remember to calculate, compare, conclude.

Question 12 (a)

This question presented few difficulties and most candidates were awarded both marks. The second mark was not awarded to the few candidates who omitted the unit, as physical quantities must have both magnitude and unit.

12 The photograph shows a sample of the mineral selenite. Selenite is made up of many long, narrow crystals.



Selenite has a refractive index of 1.52

(a) Calculate the speed of light in selenite.

(2)

$n_2 = 1.52$ $\quad$ $n_2 = \frac{\sin i}{\sin r} \cdot \frac{v_1}{v_2}$

selenite to air

$1.52 = \frac{v_1}{3 \times 10^8}$

$v_1 = 4.56 \times 10^6$

Speed of light in selenite = 4.56×10^6 m/s

ResultsPlus
Examiner Comments

This candidate is given 0 marks.

In this response, a form of the refractive index formula has been used that is not the same as that given in the list of formulae and the speeds of light in the two media have been reversed. The answer obtained is one and a half times the speed of light in a vacuum, which ought to have indicated that this needed a second attempt.

ResultsPlus
Examiner Tip

Check that answers are realistic and attempt the calculation again when they are not.

$n = \frac{c}{v}$ $\quad v = \frac{c}{n}$

$\frac{3.00 \times 10^8}{1.52} = 197368421.1 \approx 1.97 \times 10^8$

Speed of light in selenite = 1.97×10^8

ResultsPlus
Examiner Comments

This candidate is awarded 1 mark.

The calculation is correct but the unit has not been included, so the final mark has not been awarded.

ResultsPlus
Examiner Tip

Numerical quantities must include the magnitude and a unit. In the case of vector quantities, a direction is also required.

Question 12 (b) (i)

Candidates rarely included sufficient detail to be awarded a mark for this definition. It was rarely mentioned that the ray must originate in the optically denser medium and candidates often just referred to 'the angle' rather than 'the angle of incidence'.

(b) (i) State what is meant by critical angle.

(1)

The maximum angle of incidence when light travels from an optically denser material to a less dense material, beyond which the angle of refraction is greater than 90° so total internal reflection takes place.

ResultsPlus
Examiner Comments

This candidate scored 0 marks.

This response is very close to the correct answer, but it refers to an angle of refraction greater than 90°, which is not possible.

ResultsPlus
Examiner Tip

Learn definitions for all of the italicised terms in the specification, for example, by writing them from memory and checking against a list.

The angle of incidence from a more dense medium to a less dense medium where the angle of refraction is 90°.

ResultsPlus
Examiner Comments

An example of a correct response which scores 1 mark.

Question 12 (b) (ii)

The great majority of candidates were awarded both marks for this calculation. Some candidates used a different value for refractive index, such as 1.51 or 1.57. The degree sign was occasionally omitted from the final angle.

(ii) Calculate the critical angle for light in selenite.

(2)

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

$C = \sin^{-1} \frac{1}{n} = \sin^{-1} \frac{1}{1.54} = 40.5°$

Critical angle for light in selenite = 40.5°

ResultsPlus
Examiner Comments

This candidate scored 0 marks.

They have used a value of 1.54 in this calculation. The refractive index in the question is 1.52, so no marks are awarded.

(2)

$\sin^{-1}\left(\frac{1}{1.52}\right) = 41.14$

Critical angle for light in selenite = 41.14.

ResultsPlus
Examiner Comments

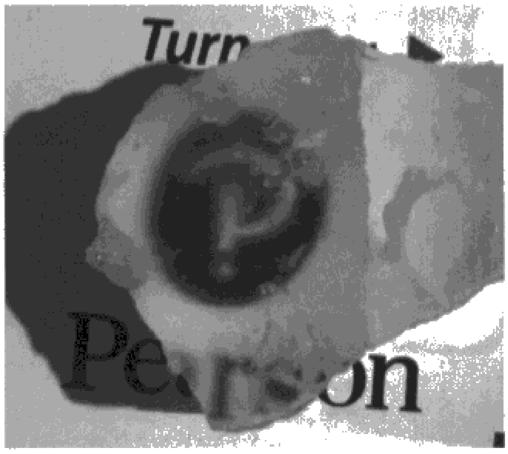
This response scored 1 mark.

The calculation is correct, but ° has been omitted from the answer, so that is treated as a missing unit.

Question 12 (c)

While there was a general appreciation of the optical fibre-like properties of this mineral, only a minority explained the process in sufficient detail. Most commonly omitted was any mention of a boundary at which total internal reflection could take place. Others missed the relevance of the critical angle. The most commonly awarded mark was for mentioning that repeated reflection took place.

(c) Selenite can act as a collection of optical fibres, so that an image of writing beneath the mineral sample appears as if it is at the upper surface as shown.



Explain how light travels through a selenite crystal.

(2)

Light passes through the crystal at more than the critical angle, this means that total internal reflection occurs. Light leaves the ~~s~~ crystal~~s~~ with the image of the light that when in.

ResultsPlus
Examiner Comments

This candidate scores 0 marks.

Light 'passes through' at more than the critical angle is not the required description for the first mark as it does not locate it at an edge. Total internal reflection is mentioned, but not that it is repeated.

Explain how light travels through a selenite crystal.

(2)

Angle of incidence inside the more dense selenite is more than the critical angle of ~~selenite~~ selenite ∴ total internal reflection occurs on the inside surfaces of selenite many time ∴ the light emerges on the other side of selenite as it has kept on totally internally reflecting.

ResultsPlus
Examiner Comments

This response scores 2 marks.

It is sufficient to locate the incidence of the light at the 'inside surfaces' of the selenite and the total internal reflection is repeated, so this scores full marks.

Question 13

While a few candidates thought that this was a question about standing waves and did not gain any credit, most candidates recognised that it was about resonance and were able to make some headway with their explanations, with over half scoring at least 3 out of 6 marks and a third being awarded 4 marks or more.

The marks obtained were often limited by a lack of detail and failure to use precise language in explanations. For example, candidates sometimes referred only to 'resonant frequency' and did not identify 720 Hz as the 'natural frequency' of the bowl from the first line of the description. Two of the indicative content points required a discussion of relative energy transfer, but many candidates did not mention energy at all. Similarly, the term 'amplitude' was not often used, despite the sound being described as quiet and then as louder. The signal generator being used to produce forced oscillations was another detail frequently omitted.

Overall, candidates were most likely to identify the natural frequency, state that the sound was loudest when resonance occurred and that this was when the driving frequency matched the natural frequency, usually set out logically so as to gain credit for linkage.

***13** The photograph shows a 'singing bowl'.

When the handles are rubbed with both hands the bowl 'sings', producing a loud note with a frequency of 720 Hz.

A vibration generator is attached to the bowl and connected to a signal generator. The signal generator is adjusted to produce frequencies from 600 Hz to 800 Hz.

At all frequencies in this range the bowl produces a sound at the applied frequency. The sound is quiet for all frequencies except 720 Hz, when it is much louder.

Explain these observations.

(6)

THE NATURAL FREQUENCY OF THE BOWL IS 720 HZ. THE VIBRATION GENERATOR PROVIDES A DRIVING FREQUENCY. WHEN THE DRIVING FREQUENCY AND NATURAL FREQENCY ARE EQUAL, MAXIMUM ENERGY TRANSFER OCCURS, HENCE THE MUCH LOUDER SOUND. THIS IS CALLED RESONANCE. AT THE OTHER FREQUENCIES IN THE RANGE, THE BOWL STILL ACTS AS AN AMPLIFIER, HOWEVER, MORE ENERGY IS LOST TO SURROUNDINGS AND THATS WHY LESS ENERGY IS TRANSFERRED AND THE SOUND IS QUIETER THAN A 720HZ.

ResultsPlus
Examiner Comments

This response scored 4 marks.

This candidate includes most of the indicative content points, but lacks some specific detail required for mark point 3 and mark point 6. It does not refer explicitly to the low energy transfer to the bowl at non-matching frequencies, nor does it mention amplitude, which is maximum when resonance occurs.

When the bowl is rubbed with both hands it oscillates at the natural frequency of the bowl, producing a loud note at 720 Hz, so therefore 720 Hz must be the natural frequency of the bowl.
When a vibration generator is attached to the bowl, it forces the bowl to oscillate at the driving frequency of the generator, so a loud sound is not produced, as the driving frequency at this point ≠ 720Hz.
When the signal generator is adjusted to 720 Hz, natural frequency = driving frequency and resonance occurs. The rate of energy transfer is the greatest at 720 Hz, so the bowl resonates with maximum amplitude, producing a loud sound.

ResultsPlus
Examiner Comments

This candidate scores 5 marks.

This is a very well structured response that only omits one indicative content point, which is that little energy is transferred at frequencies other than 720 Hz.

Question 14 (a)

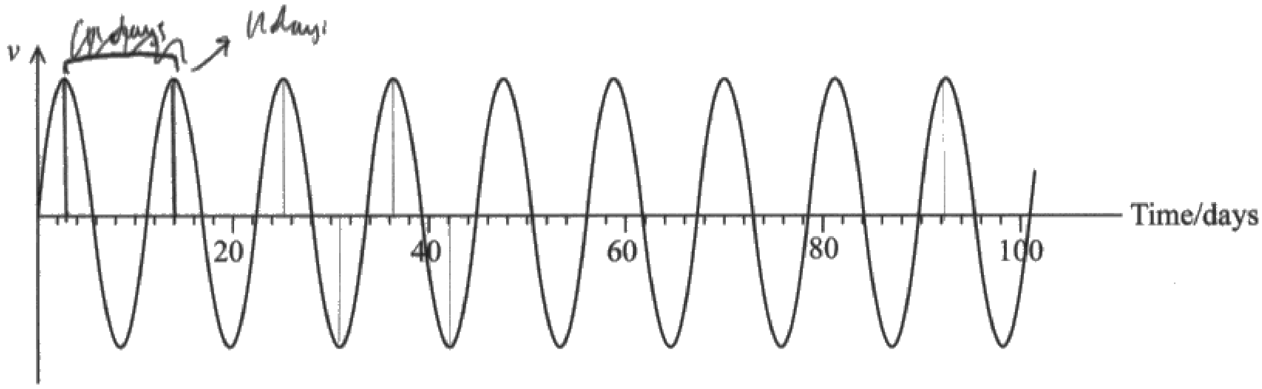
While a large majority of candidates gained some credit for this question, only about a third were awarded more than a single mark. They were asked about obtaining data, which showed velocity varying in magnitude and direction; but many wrote the Doppler equation without consideration of how Δf could be obtained and thus did not describe any actual measurements of frequency or wavelength, whether from the star or in the laboratory.

Candidates that described the difference between objects approaching or moving away from an observer often only referred to blue shift or red shift, or to squeezing or stretching of waves, and did not make a statement about an increase or decrease in frequency or wavelength. The question required both directions to be addressed and candidates did not always do this. Some candidates linked Doppler shift to the distance from the Earth, saying that frequency increased when the planet was closer, and others took this as far as invoking the Hubble relationship which only applies at cosmological distances and not for the nearest star to the Sun.

14 In 2016 astronomers announced the discovery of an Earth-like planet orbiting Proxima Centauri, the closest star to the Sun.

The planet was detected because of the small movement of the star as the planet orbited. The movement was detected using the Doppler shift in the frequency of light travelling to the Earth.

The graph shows how the component of the star's velocity v towards the Earth varied over time.



(a) Explain how the Doppler shift was used to obtain the data shown on the graph.

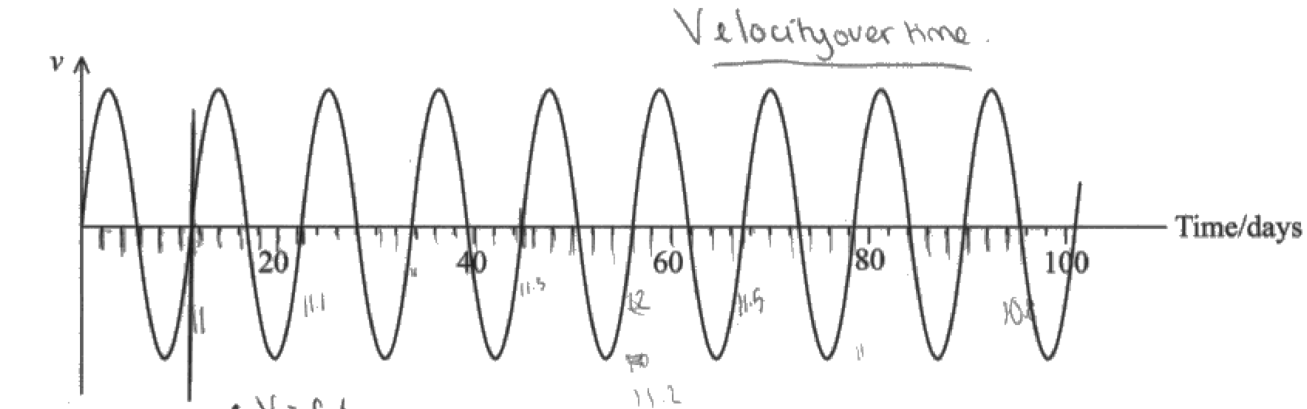
(4)

Frequency of light was measured from the planet, and then compared with the frequency of light from the same source in a lab.* The Doppler shift equation would be used; $\frac{\Delta f}{f} = \frac{v}{c}$, so velocity $= \frac{\Delta f}{f} \times c$. * Difference between the two is found (Δf), and this is divided by the "lab frequency" (f). Positive velocity means decreasing frequency (as λ is increasing) from red shift, and vice versa for blue shift. This is measured every two days in order to plot the graph.

ResultsPlus
Examiner Comments

This candidate scored 3 marks.

The first three points on the mark scheme are awarded for this response. In regard to the fourth marking point, this answer is a bit confused. The question states that the graph is for the star's velocity towards the Earth, but this response links positive values to decreasing frequency, which should be obtained for negative velocities. A correct answer would also require a correct description of the reverse situation.



V = H   • V = f λ.

(a) Explain how the Doppler shift was used to obtain the data shown on the graph.

(4)

• They measured the wavelength of the light being emitted from the star from earth. They also measured what the wavelength from the star should look like if the star wasn't moving relative to our earth. The found the difference between the two values. $\frac{\Delta\lambda}{\lambda_{\text{(actual wavelength)}}} = \frac{v}{c}$ They then timesed the ratio of wavelengths by c to give the speed of the velocity relative to us. The doppler shift meant that when the star was moving away from us the ~~Δλ was~~ wavelength we saw was larger than it actually was. As it moved further and further away this Δλ got bigger because as things move further away from us $v = H_0 d$ their speed gets larger.

ResultsPlus
Examiner Comments

This candidate scored 3 marks.

As in the previous example, the first three marks are awarded. In this case recession is correctly linked to an increase in wavelength, although it states that the effect would increase with increasing distance, whereas at the extreme point the velocity away from Earth would be zero. The effect when approaching the Earth is not mentioned, suggesting that this candidate may be thinking of the expansion of the Universe.

Question 14 (b)

A majority of candidates were able to calculate a reasonable value of angular velocity in Q14(b)(i), although they frequently only used a single cycle from the graph to determine the period and therefore, did not all achieve the required accuracy for the final answer.

In Q14(b)(ii), many knew how to use the angular velocity to calculate the distance of the planet from the star, although a fair proportion did not make their way through the sequence of algebraic manipulation successfully, with incorrect cancelling of *r* being seen quite often after equating gravitational force to centripetal force. It was not entirely uncommon to see a candidate attempting to bypass this process by using the value of $g = 9.81$ m s^{-2} in $g = GM/r^2$, although this was an entirely different star system. Candidates did not always cube root the value of r^3 attained during the calculation. The mass of the Sun was sometimes used without applying the factor of 0.12.

(b) (i) Use the graph to show that the angular velocity of the planet is about 6×10^{-6} radian s^{-1}.

(3)

$\omega = \frac{2\pi}{T}$ $\quad T = \frac{90}{8} = 11.25$ days

$11.25 \times 3600 \times 24 = 972000$ s

$\omega = \frac{2\pi}{972000} = 6.46 \times 10^{-6}$ rad s^{-1}

(ii) The mass of Proxima Centauri is 0.12 times the mass of the Sun.

Determine the distance of the planet from Proxima Centauri.

mass of Sun = 1.99×10^{30} kg

(3)

$0.12 \times 1.99 \times 10^{30} = 2.388 \times 10^{29}$ kg

$F = m\omega^2 r$

$F = \frac{GMm}{r^2}$

$\frac{GM}{r^2} = \omega^2 r$

$GM = \omega^2 r^3$

$\sqrt[3]{\frac{GM}{\omega^2}} = r = \sqrt[3]{\frac{6.67 \times 10^{-11} \times 2.388 \times 10^{29}}{6 \times 10^{-6}}} = 1.38 \times 10^{8}$ m

Distance = 1.38×10^{8} m

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Examiner Comments

Q14(b)(i) is awarded 3 marks.

Q14(b)(ii) is awarded 1 mark.

In Q14(b)(i), the calculation is correct and there is evidence of multiple cycles having been used in the determination of the period, so full marks are awarded.

In 14(b)(ii), the relevant formulae have been equated and rearranged correctly, but in the substitution, the angular velocity has not been squared.

ResultsPlus
Examiner Tip

When a formula has a power term, eg ω^2, don't suddenly miss off the index when substituting or forget it in the calculation.

(b) (i) Use the graph to show that the angular velocity of the planet is about 6×10^{-6} radian s^{-1}.

(3)

$T = \frac{2\pi}{\omega}$ $\quad \omega = \frac{2\pi}{T}$ $\quad T = 11$ days

$= (11 \times 24 \times 3600)$ s

$\omega = \frac{2\pi}{950400}$ $\quad = 950400$ s

$= 6.61 \times 10^{-6}$ rad s^{-1}

(ii) The mass of Proxima Centauri is 0.12 times the mass of the Sun.

Determine the distance of the planet from Proxima Centauri.

mass of Sun = 1.99×10^{30} kg

(3)

$0.12 \times 1.99 \times 10^{30} = 2.388 \times 10^{29}$

$F = ma = \frac{GM_1M_2}{r^2}$

$m_2 r \omega^2 = \frac{GM_1M_2}{r^2}$

$\omega^2 = \frac{GM}{r^3}$

$r^3 = \frac{GM}{\omega^2}$

$r = \sqrt[3]{\frac{GM}{\omega^2}} = \sqrt[3]{\frac{6.67 \times 10^{-11} \times 2.388 \times 10^{29}}{(6.61 \times 10^{-6})^2}} = 7.14 \times 10^9$ m

Distance = 7.14×10^9 m

ResultsPlus
Examiner Comments

Q14(b)(i) is awarded 2 marks.

Q14(b)(ii) is awarded 3 marks.

In Q14(b)(i) the correct method has been used for the calculation, but only one cycle has been used in the determination of the period.

Q14(b)(ii) is correct for full marks.

Question 15 (a)

This was very rarely completed incorrectly, with a few candidates reversing the numerator and denominator or multiplying where they should be dividing. A few went astray with kHz, treating the frequency as 26.0 Hz rather than 26 000 Hz.

15 The photograph shows an ultrasonic mouse repeller used in a house.

The mouse repeller produces ultrasound that repels mice but cannot be heard by humans. The mouse hears ultrasound directly and by reflection from the walls.

The mouse repeller produces ultrasound of frequency 26.0 kHz.

speed of sound = 340 m s^{-1}

(a) Calculate the wavelength of the ultrasound produced.

(2)

$s = \lambda f \quad \lambda = \frac{s}{f} = \frac{340}{26 \times 10^{6}} = 1.31 \times 10^{-5}$ m

Wavelength = 1.31×10^{-5} m

ResultsPlus
Examiner Comments

This response gains 1 mark.

In this response kHz has been interpreted as 10^{6} Hz rather than 10^{3} Hz, so the answer is a thousand times too small.

ResultsPlus
Examiner Tip

Be sure to know the standard SI prefixes and be able to apply the correct power of ten.

The mouse repeller produces ultrasound that repels mice but cannot be heard by humans. The mouse hears ultrasound directly and by reflection from the walls.

The mouse repeller produces ultrasound of frequency 26.0 kHz.

speed of sound = 340 m s^{-1}

(a) Calculate the wavelength of the ultrasound produced.

(2)

$v = f\lambda$

$\lambda = \frac{v}{f} = \frac{340}{26 \times 10^3} = 0.01307692$

ResultsPlus
Examiner Comments

This response scores 1 mark.

This calculation is fully correct, but the unit m has been omitted from the answer.

Question 15 (b)

While the great majority of candidates were awarded at least one mark for this question, for stating that two waves meet in one of several different ways, relatively few achieved both marks. A common reason for this was that they referred to the sum of amplitudes at a point rather than the sum of displacements. The displacement at a point will always be equal to the sum of the displacements of the contributing waves, whereas the amplitude at a point will depend on the phase difference between the contributing waves as well as their amplitudes; as candidates know from the description of a node as a point with zero amplitude and an antinode as a point with maximum amplitude. Both result from waves with the same amplitudes, but the amplitude is clearly not the sum of amplitudes because the maximum displacement is different at each of these points.

(b) State what is meant by superposition of waves.

(2)

When two waves ~~to~~ interfere with each other and their amplitudes are totalled to make the new ~~ap~~ amplitude at that point.

ResultsPlus
Examiner Comments

This candidate scores 1 mark.

In this response there is reference to the amplitude at a point being equal to the sum of the amplitudes, when it should have described it in terms of displacement.

When two waves of similar amplitude, ~~and~~ frequency and of the same type interfere. The total displacement is the vector sum of the displacements of the individual waves.

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This is an example of a correct response and scores 2 marks.

Question 15 (c)

Very few candidates achieved full marks for this question, but many scored 3 or 4, usually for describing the formation of standing waves and often for suggesting that mice would not hear the sound at a node. Candidates were less successful at responding to the given context, such as noting that the separation of antinodes was less than a centimetre so a mouse could not avoid the sound completely, or in realising that a room is a three-dimensional space so there will be reflected sound from other directions. Having given a standard explanation of the formation of standing waves, most were happy to accept the statement in the question without further consideration of its accuracy, although the question asked them to evaluate the suggestion.

Some candidates lacked sufficient detail to gain credit for more than stating that waves would meet and interference would occur. They did not refer to phase difference, or they confused it with path difference, and they did not relate this to amplitude. Some did not refer to waves being in ‘antiphase’, but only to ‘out of phase’, which applies to anything that is not in phase.

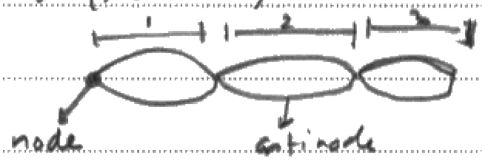
(c) A student makes the following suggestion.

"If the ultrasound reflects off a wall directly opposite the mouse repeller a standing wave is formed, so there will be areas in the room where the mice will not hear the ultrasound."

Evaluate this suggestion.

(6)

A standing waves is caused by the superposition / interference of a reflected progressive wave. A standing waves has regions of max amplitudes called antinodes and regions of no amplitude called nodes (see below).



If the sound waves are reflected and a standing wave is formed, this means that there are node regions where the ~~waves~~ reflected wave arrives out of phase to the original waves and superimpose to cancel out. Therefore no sound will be heard in these region

However, there are areas around the room where these waves superimpose to create an amplified wave.

This suggestion is therefore justified on the ~~fo~~ principle of standing wave superposition.

(Total for Question 15 = 10 marks)

ResultsPlus
Examiner Comments

This candidate scores 3 marks.

The three marks are awarded for marking points 1, 2 and 4. There is reference to 'superimpose', which would not be credited, but the mark was already awarded for 'superposition' in the first line. Marking point 3 has not been awarded because it only says that waves arrive 'out of phase', whereas we required 'antiphase'.

When a wave is reflected, it does interfere with the incident wave to form a standing wave. Where the two waves are in phase, constructive interference occurs and antinodes (areas of maximum amplitude) are formed. In these areas, the sound would be even louder for the mice. Where they destructively interfere, nodes are formed (areas of 0 amplitude) so the mice would not be able to hear anything in theory. However, in practice, reflected waves have less energy than incident waves as they can be scattered or absorbed by the surface (especially if the material is absorbing). This means that the reflected wave will have a lower amplitude so will not completely cancel out at nodes. The sound will be quieter but still present.

ResultsPlus
Examiner Comments

This candidate scores 4 marks.

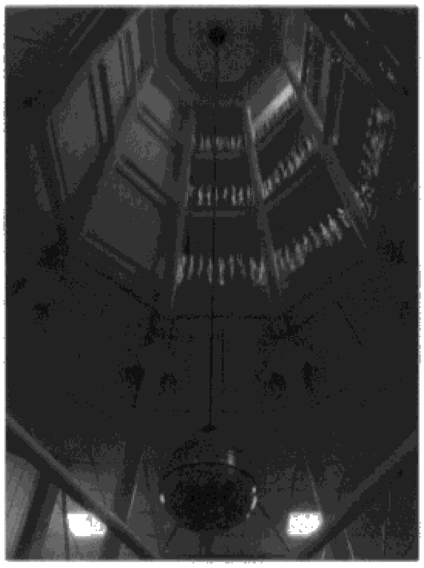
The description of standing wave formation is awarded 3 marks, marking point 3 is not awarded because there is no reference to antiphase.

There is a good discussion of the actual situation along the lines of incomplete cancellation because of partial absorption of the reflected wave, but only 1 mark has been awarded because there is not an explicit statement that the suggestion is incorrect (as necessitated by 'evaluate this suggestion').

Question 16 (a)

The great majority of candidates calculated the length of the pendulum but were unsuccessful in subtracting the radius of the sphere to determine the length of the wire, either subtracting the diameter or leaving it as 10.6 m. There was not a wide realisation that the length of the pendulum is the distance from the point of suspension to the centre of mass of the sphere, rather than the bottom of the sphere.

16 The photograph shows an example of a Foucault pendulum.



This is a pendulum that consists of a massive sphere, suspended by a long wire from a high ceiling. Over time the vertical plane through which the pendulum swings appears to rotate because of the rotation of the Earth.

mass of sphere = 28.0 kg

(a) The pendulum makes 8 complete oscillations in 52.2 s.

Show that the length of the wire supporting the sphere is about 10 m.

diameter of sphere = 60.0 cm

(4)

$T = \frac{52.2\,s}{8} = 6.525\,s$.

$T = 2\pi\sqrt{\frac{L}{g}}$

$\therefore 6.525 = 2\pi\sqrt{\frac{L}{9.81}}$.

$\frac{L}{9.81} = \left(\frac{6.525}{2\pi}\right)^2$

10.58 m.

$L = 9.81 \times \left(\frac{6.525}{2\pi}\right)^2 = 10.579\ldots \approx$ ~~10m~~.

As centre of mass of the sphere = centre of the sphere

$\therefore L_{wire} = L - r = 10.58\,m - 0.6\,m = 9.98\,m \approx 10\,m$.

ResultsPlus
Examiner Comments

This candidate scores 2 marks.

The pendulum length has been calculated, but the full diameter has been subtracted.

ResultsPlus
Examiner Tip

When the data includes a diameter, be careful when deciding whether the radius or the diameter is required for the calculation.

$T = 2\pi\sqrt{\frac{l}{g}}$ $\quad T = \frac{52.2}{8} = 6.525\text{s}$ ~~t = 10m~~

$\frac{T}{2\pi} = \sqrt{\frac{l}{g}}$ $\quad l = 9.81 \times \left(\frac{6.525}{2\pi}\right)^2$

$\left(\frac{T}{2\pi}\right)^2 = \frac{l}{g}$ $\quad = 10.6\text{m} \approx 10\text{m}$

$l = g\left(\frac{T}{2\pi}\right)^2$

ResultsPlus
Examiner Comments

This candidate scores 1 mark.

The dimensions of the sphere have not been considered and 10.6 m has been roughly equated to 10 m, even though it is 11 m to 2 significant figures. In 'show that' questions, the final answer must be given to one significant figure more than in the question and it must round to the value stated in the question, which 10.6 m does not.

ResultsPlus
Examiner Tip

In a 'show that' question, make sure your answer has an additional significant figure and rounds to the value stated in the question.

Question 16 (b)

While a minority of candidates completed these two parts successfully, many made a small error along the way, so that typically candidates scored between 3 and 5 marks out of 6 for this question.

Most candidates were able to calculate the minimum radius required for the wire in Q16(b)(i), or the stress for each of the suggested wires supporting the given sphere, but often did not explain their choice of wire in sufficient detail.

In Q16(b)(ii), some candidates used the length calculated in Q16(a) or the minimum radius calculated in Q16(b)(ii), and some used the breaking stress from Q16(b)(i) directly. A few candidates could not recall the formula for cross-sectional area or used diameter instead of radius.

(b) During refurbishment, the pendulum is taken down and the wire is replaced.

Steel wires of the following diameters are available:

0.71 mm   0.91 mm   1.22 mm   1.63 mm   2.03 mm

(i) Explain which of these wires is the thinnest that could be used to support the sphere safely.

breaking stress of steel = 3.10×10^8 N m^{-2}

(3)

$\sigma = \frac{F}{A}$ $F = mg$ & $A = \pi\left(\frac{d}{2}\right)^2$

$A = \frac{mg}{\sigma} = 8.86 \times 10^{-7}\ m^2 = \pi\left(\frac{d}{2}\right)^2$

$\sqrt{\frac{A4}{\pi}} = d = 1.06 \times 10^{-3}\ m = 1.06\ mm$

hence, 1.22 mm is the thinnest.

(ii) The wire identified in part (i) is used for the pendulum, the unstretched length of the new wire is 11.2 m.

Calculate the extension of the new wire when the sphere is attached.

Young Modulus for steel = 200 GPa

(3)

$E = \frac{\sigma}{\varepsilon} \Rightarrow \varepsilon = \frac{\sigma}{E}, \quad \sigma = \frac{F}{A} = \frac{(28)(9.81)}{\pi\left(\frac{1.22 \times 10^{-3}}{2}\right)^2}$

$\sigma = 0.235 \times 10^{9}$ Pa

$\varepsilon = \frac{0.235 \times 10^{9}}{200 \times 10^{9}} = 1.17 \times 10^{-3}$ m

$\varepsilon = \frac{\Delta x}{e} \Rightarrow \Delta x = (1.17 \times 10^{-3})(11.2)$

$\Delta x = 0.01315$

$\simeq 13.2$ mm

Extension = 13.2 mm

ResultsPlus
Examiner Comments

Q16(b)(i) scores 2 marks.

Q16(b)(ii) scores 3 marks.

In Q16(b)(i) the correct diameter has been calculated and the correct wire has been chosen, but there is insufficient explanation for the choice.

Q16(b)(ii) is fully correct.

(b) During refurbishment, the pendulum is taken down and the wire is replaced.

Steel wires of the following diameters are available:

0.71 mm   0.91 mm   1.22 mm   1.63 mm   2.03 mm

(i) Explain which of these wires is the thinnest that could be used to support the sphere safely.

breaking stress of steel = 3.10×10^8 N m^{-2}

(3)

F= mg

= 28 × 9.81

= 274.68 N

~~breaking st~~ , 0.71 : ~~breaking~~ stress = 274.68 ÷ (π(0.71 ÷ 2 / 1000)^2)

= 6.94 × 10^8 Nm^{-2} > 3.1×10^8

0.91 : stress = 274.68 ÷ (π(0.91 ÷ 2 / 1000)^2)

= 4.22 × 10^8 Nm^{-2} > 3.1×10^8

1.22 : stress = 274.68 ÷ (π(1.22 ÷ 2 / 1000)^2)

= 2.35 × 10^8 Nm^{-2} < 3.1×10^8

∴ 1.22mm is the thinnest that could be used to support

(ii) The wire identified in part (i) is used for the pendulum, the unstretched length of the new wire is 11.2 m.

Calculate the extension of the new wire when the sphere is attached.

Young Modulus for steel = 200 GPa

(3)

Young Modulus $= \frac{\text{stress}}{\text{strain}}$

Strain $= \frac{2.35 \times 10^{8}}{200 \times 10^{12}}$

$= 1.175 \times 10^{-6}$

extension $= 1.175 \times 10^{-6} \times 11.2$

= ~~0.0132 m~~ ~~1.32×10^{-5} m~~

Extension = 1.32×10^{-5} m ~~0.0132 m~~

ResultsPlus
Examiner Comments

Q16(b)(i) scores 3 marks.

Q16(b)(ii) scores 2 marks.

In Q16(b)(i) the stress has been calculated for successive wires, starting with the thinnest. A comparison has been made with the breaking stress for each in turn, allowing the first that is strong enough to be identified easily. This pattern of solution and the final comment were sufficient to be awarded full marks.

In Q16(b)(ii) GPa have been interpreted as 10^{12} Pa rather than 10^{9} Pa, so there is a power of ten error in the final answer which is given two marks.

Question 16 (c)

Very few candidates were able to make relevant points in their explanation. They often mentioned that air resistance acts on the pendulum in both cases, but did not go on to identify air resistance as a force or say that the force is equal, whatever the mass of the pendulum. There was sometimes evidence of an appreciation that this would cause energy dissipation, but candidates rarely realised that the rate would initially be the same, so that the larger energy store of the heavier pendulum would take longer to be fully dissipated. They were more likely to link mass to a different rate. Explanations sometimes corresponded to the momentum version for the second marking point and energy for the third, so only one of these marks could be awarded.

A significant proportion of candidates found a formula involving period and mass $T = 2\pi\sqrt{(m/k)}$ and tried to shoe-horn it into an explanation, linking increased mass to an increased period and suggesting that a heavier pendulum would therefore oscillate for longer. The lack of a quantity corresponding to *k* should have indicated that this was not the formula to use. Using formulae as part of an explanation is only advisable where it is a relevant formula.

Other incorrect ideas included linking the greater tension for a heavier mass to a greater centripetal force and therefore a greater speed, and also a greater mass resulting in a greater extension and therefore a longer period by $T = 2\pi\sqrt{(l/g)}$.

(c) To show the rotation of the Earth, the pendulum needs to oscillate for several hours.

Explain how using a heavy sphere is better than using a light sphere of the same diameter.

(3)

The main resistive forces acting is air resistance which depends on diameter not mass so resistance force is pretty much same for heavy or light sphere. $F = ma$ so if m decreases, F is constant a increases, in this case a is towards $0\ ms^{-1}$ so a light sphere is accelerated to rest in a shroter time ($\frac{\Delta V}{\Delta t} = a$) so a heavy sphere is more likely to oscillate for several hours

(Total for Question 16 = 13 marks)

ResultsPlus
Examiner Comments

This candidate scores 2 marks.

Overall, this is a fairly good description. There is, however, some imprecision in the language such as, 'pretty much the same' rather than 'approximately equal to', and 'a is towards 0 m s^{-1}' rather than a reference to deceleration or negative acceleration. This last point meant that only two marks were awarded.

with the same diameter the damping applied to the sphere due to drag in the air remains equal however the energy within the system is increased as the pendulum has more mass as $E = mgh$ and E_k at the equilibrium $= \frac{1}{2}mv^2$, and so energy dissipates at the same rate but the pendulum has more energy and so oscillates over a longer time before losing all energy.

(Total for Question 16 = 13 marks)

ResultsPlus
Examiner Comments

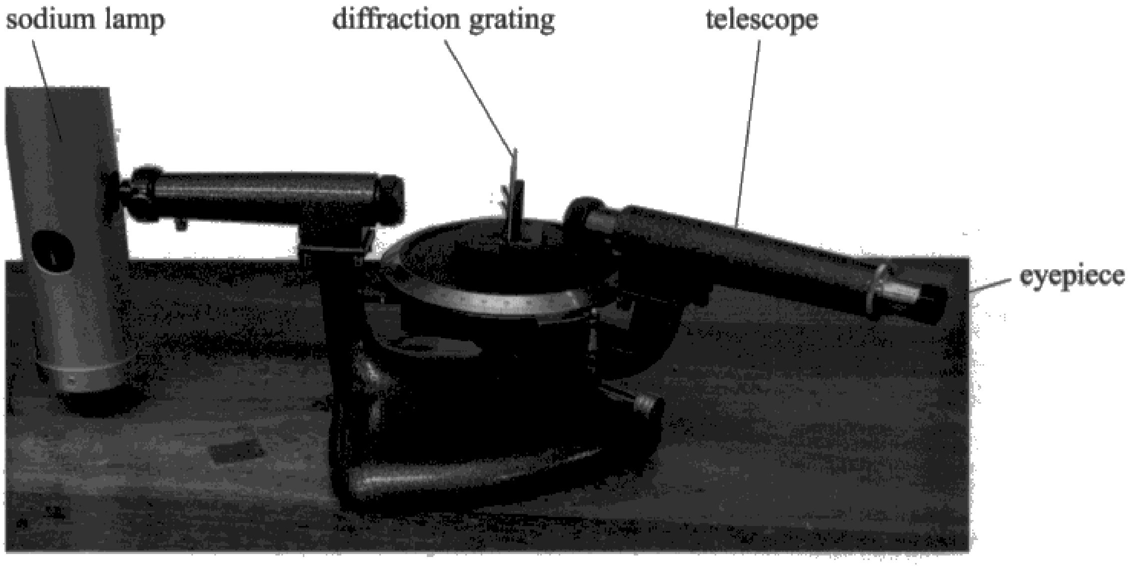
This candidate scores 2 marks.

This answer also shows a good appreciation of the situation, but we required a more explicit reference to work done for the award of the second mark.

Question 17 (a)

Most candidates were able to use the lens equation to calculate 250 mm, but a substantial proportion used this as the object distance and 16.7 mm as the image distance when calculating magnification, so they were only awarded the first mark. Within the question itself, the statement that the eyepiece lens 'uses this real image as an object', should have informed candidates which way round the values should have been applied.

17 The photograph shows a school spectrometer.



The spectrometer allows parallel rays of light to be passed through a diffraction grating and the resulting angles of diffraction to be measured.

(a) In the telescope, light from the grating is focused to make a real image 16.7 mm in front of the eyepiece lens. The eyepiece lens then uses this real image as an object to produce a magnified virtual image for the observer.

Calculate the magnification produced by the eyepiece lens.

focal length of eyepiece lens = 17.9 mm

(3)

$v = 16.7\ mm \quad f = 17.9\ mm \qquad \frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

$mag = \frac{v}{u} \qquad \frac{1}{u} + \frac{1}{16.7} = \frac{1}{17.9}$

$= \frac{16.7}{249.1} = 0.067 \qquad \frac{1}{u} = \frac{1}{17.9} - \frac{1}{16.7}$

$\frac{1}{u} = \frac{1.20}{298.93} \qquad u = 249.1\ mm$

Magnification = 0.067

ResultsPlus
Examiner Comments

This candidate scores 1 mark.

The image distance calculated using the lens equation has been treated as the object distance in the calculation of magnification, so only the first mark has been awarded.

$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$

$-\frac{1}{v} = \frac{1}{f} - \frac{1}{u} \Rightarrow \frac{1}{v} = -\frac{1}{f} + \frac{1}{u} \Rightarrow \frac{1}{v} = -\frac{1}{17.4\times10^{-3}} + \frac{1}{16.7\times10^{-3}} = 4.01$

$v = 0.249$

$M = \frac{0.249}{16.7\times10^{-3}} = 14.92$ diapers

Magnification = 14.9 diapers

ResultsPlus
Examiner Comments

This candidate scores 2 marks.

The calculations are all correct but the magnification has been given the unit of the power of a lens, and as a result of this incorrect unit the final mark is not awarded. Magnification is a ratio of two distances, or two heights, and so does not have a unit.

ResultsPlus
Examiner Tip

Although numerical answers nearly always require a unit, when they are ratios they do not. Examples of this are magnification and the trigonometrical quantities, sine, cosine and tangent.

Question 17 (b) (i)

There was a full spread of scores for this question which required a detailed explanation of the formation of an emission spectrum, with candidates typically gaining 2 or 3 marks and the best answers being awarded full marks.

The most commonly made point was that electrons become excited, followed by reference to discrete energy levels. These marks required a single piece of information, but all of the rest involved at least two linked ideas. A large proportion were able to link moving to a lower energy level, giving out energy and photons, but some did not include all three, often omitting the word 'photon'. Other marking points appeared progressively more difficult and lacked sufficient detail, particularly linking certain frequencies to certain energy transitions rather than certain energy levels.

Some candidates described the situation for an absorption spectrum rather than for an emission spectrum and a fair number described aspects of the photoelectric effect in their answers.

(b) The spectrometer and diffraction grating are used to analyse the light from a sodium lamp. In the sodium lamp, sodium is heated until it becomes a vapour and an electric current is passed through it. The vapour then emits light.

After the light passes through the diffraction grating a line spectrum is observed.

(i) Explain why only certain wavelengths are observed.

(6)

each electronhas a specific energy level. When the electric current passes through the hot vapour, the electron gains energy. They become excited and move to a higher energy level. This however is not stable so the electron will move back down to its energy level to become stable again, releasing energy in the form of light. Depending on the difference between the electrons stable energy level / and the energy levelwhere it wentto when it was excited, the wavelength emitted will vary. The wavelength will be then absorbed in a line spectrum. The background is black and the wavelength emitted will appear on the spectrum. Only certain wavelengths are absorbed because the amount of energy each electron gets from the emission process is different.

ResultsPlus
Examiner Comments

This candidates scores 2 marks.

The first two marking points are awarded for the first two sentences. In the third sentence we read about energy being released in the form of light, but a reference to photons was required. There is a suggestion of the idea in the fourth marking point, but not in any detail, and the answer then gets a bit mixed up, referring to absorption but describing the appearance of an emission sprectrum.

Electrons in the sodium vapour is transferred energy from the electric current. The energy excites the electrons to move up to higher energy levels. The excited electrons are unstable and returns to their ground states by emitting energy in the form of photons. There are discrete energy levels in sodium and therefore only discrete energy differences ~~exe~~ exist between the energy levels. So the electrons ~~of~~ emit photons with certain energy. $E = hf = \frac{hc}{\lambda}$
Therefore, only certain wavelengths are observed.

ResultsPlus
Examiner Comments

This candidate scores 5 marks.

This is a well structured response and only misses marking point 4 because it does not state that the energy of the emitted photon is equal to the difference in energy between the energy levels.

Question 17 (b) (ii)

Candidates generally selected the appropriate formula, although not all of them realised that they could then use an angle of 90° to determine the smallest grating spacing allowing a third order to be visible. Overall, nearly half could complete the calculation. While most of these candidates were able to choose the correct grating, very few explained it in sufficient detail, a common omission being to refer to smaller uncertainty rather than smaller percentage uncertainty.

Some candidates calculated the third order angle for all of the available gratings, increasing the work needed but seemingly making the explanation of the choice a bit easier for these candidates.

(ii) Diffraction gratings with the following spacings are available:

$d/10^{-6}$ m	1.0	1.7	2.0	3.3

Explain which would be the best spacing to use to measure the diffraction angle for the third order maximum for yellow light of wavelength 589 nm.

(3)

$n\lambda = d\sin\theta$ $\quad$ $3\lambda = d(\sin 90)(1)$

$3 \times 589 \times 10^{-9} = d$

$d = 1.767 \times 10^{-6}$

1.7×10^{-6} m would be the best spacing because this is when the angle measured is the largest so there will be a lower percentage uncertainty.

ResultsPlus
Examiner Comments

This candidate is awarded 2 marks.

The calculation has been completed to find the fringe spacing producing a third order maximum at 90°, but the wrong grating has been chosen from those available.

$d \sin\theta = n\lambda$

$d \sin\theta = 3 \times 589 \times 10^{-9}$

$\sin\theta = \frac{3 \times 589 \times 10^{-9}}{d}$

$d = 1 \times 10^{-6}$ or 1.7×10^{-6} produce ~~[illegible]~~ $\sin\theta$ = greater than 1 so no solution

$d = 2 \times 10^{-6}$ ~~[illegible]~~ $\rightarrow \theta = 62.1°$

$d = 3.3 \times 10^{-6} \rightarrow \theta = 32.3°$

~~2×10^{-6} m grating is too large to see a third order maximum~~

3.3×10^{-6} m angle is small than grating of 2×10^{-6} m therefore larger angle can be measure more easily with less uncertainty

$\therefore$ 2×10^{-6} is the best spacing

ResultsPlus

Examiner Comments

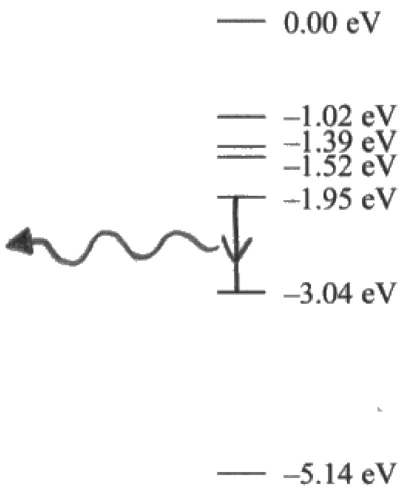
This candidate is awarded 2 marks.

A successful approach was adopted here, performing the third order calculation for each grating in order of increasing grating spacing, which made identification of the correct choice straightforward. The final mark was not awarded, however, because the answer states that this grating would have less uncertainty. The uncertainty would remain the same in each case, so we required reference to smaller percentage uncertainty.

Question 17 (c)

About three quarters of candidates gained at least 3 marks. A majority of those completing the calculation added the arrow to the diagram correctly. Of those who did not, most drew the arrow going upwards, some omitted it and some drew it between the wrong levels or too roughly to judge.

(c) The diagram shows some of the energy levels in a sodium atom.



Add an arrow to the diagram to show the transition involved in the emission of yellow light of wavelength 589 nm.

Show your working below.

(4)

$E = hf \quad f = v/\lambda = \frac{(3\times10^{8})}{(589\times10^{-9})} = 5.09\times10^{14}$ Hz (3sf)

$E = (6.63\times10^{-34}) \times (5.09\times10^{14}) = 3.38\times10^{-19}$ J (3sf)

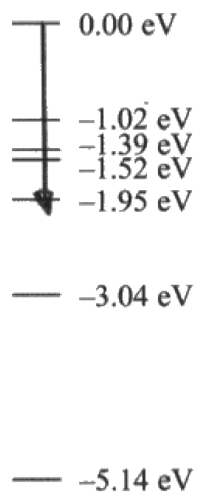
$(3.38\times10^{-19})/(1.6\times10^{-19}) = 2.11$ eV (3sf)

When light is being emitted, photon is being emitted, electron is losing energy.

ResultsPlus
Examiner Comments

This candidate is awarded 3 marks.

The calculation of the energy difference for the stated wavelength is fully correct, but the wrong transition has been identified on the diagram. This is a difference of 1.1 eV when it should be 2.1 eV.



Add an arrow to the diagram to show the transition involved in the emission of yellow light of wavelength 589 nm.

Show your working below.

(4)

$v = f\lambda \quad \frac{(3\times10^{8})}{(589\times10^{-9})} = 5.09\times10^{14}\,Hz$

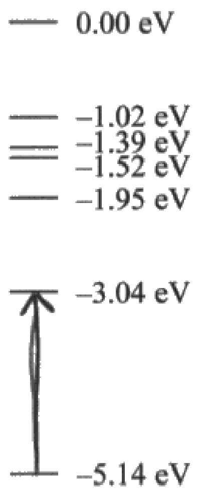
$E = hf \quad E = (6.63\times10^{-34})\times(5.09\times10^{14}) = 3.3769\times10^{-19}\,J$

$\frac{3.3769\times10^{-19}}{(1.6\times10^{-19})} = 2.11\,eV$ must be lost

ResultsPlus
Examiner Comments

This candidate is awarded 3 marks.

The calculation is correct, but the candidate has not put the arrow on a specific level but just extended it downwards by about 2.1 eV, missing the point that transitions are only possible between discrete energy levels.



Add an arrow to the diagram to show the transition involved in the emission of yellow light of wavelength 589 nm.

Show your working below.

(4)

$V = f\lambda \quad \frac{3\times10^{8}}{5.89\times10^{-7}} = f = 5.09\times10^{14}$

$E = hf = 6.63\times10^{-34} \times 5.09\times10^{14} = 3.38\times10^{-19}$

$\frac{3.38\times10^{-19}}{1.6\times10^{-19}} = 2.11\,\text{eV}$

ResultsPlus
Examiner Comments

This response scores 3 marks.

The calculation is correct and the correct levels have been chosen, but the arrow goes upwards as for energy absorption rather than the required emission.

Question 18 (a)

This question required two linked points, but many did not do this and consequently only about a quarter of the candidates were awarded a mark for their answers. While most realised that alpha particles would not penetrate the plastic, this was not linked to a benefit in the majority of cases. It appeared to be the case that some candidates had not noticed the part of the question that told them that helium gas would be collected, 'since an alpha particle is a helium nucleus', so they did not then link the prevention of alpha penetration with the build-up of helium.

18 An old type of camping lamp used a 'gas mantle'. The gas mantle is heated by the gas flame on the lamp and emits a bright white light. Gas mantles used to contain thorium-230.

Thorium-230 decays by alpha emission to form an isotope of radium. A student keeps a radioactive gas mantle in a sealed polythene bag. The student suggests that over a period of a year a significant volume of helium gas will be collected, since an alpha particle is a helium nucleus.

(a) Give reasons why the sealed plastic bag is suitable for collecting the gas.

(2)

Alpha particles are stopped by a few cm of air so would not be able to penetrate through and escape the plastic bag as they would be stopped as they lose energy.

ResultsPlus
Examiner Comments

This response scores 0 marks.

This is a good description of alpha particle absorption, but it is not linked to either reason for suitability.

(2)

α has a small 5–7cm range in air and is absorbed by paper/ is absorbed by the polythene bag $\therefore$ can be used to collect the gas as helium gets trapped in the bag and α is absorbed $\therefore$ cannot cause any harm to humans.

ResultsPlus
Examiner Comments

This response scores 2 marks.

This is a good example of a two mark answer, with alpha particle absorption being linked to trapping the gas and to safety.

Question 18 (b) (iii)

Most candidates obtained marks for this question, but they did not all reach the correct final result. A suitable formula was generally selected, but the *pV* version was more difficult to use correctly and a range of errors were made after selecting the formula, including: not converting temperature from °C to K, not finding the square root of the mean squared speed, and using an incorrect mass (frequently the mass of the sample rather than the mass of a helium atom). Candidates who did not perform the square root did not seem troubled by the idea of molecular speeds of nearly two million metres per second, whereas one might expect them to realise that speeds of the order of a thousand metres per second should be expected at room temperature.

(iii) Calculate the root mean square speed of the atoms in the helium gas at a temperature of 22.0 °C.

(3)

$\frac{1}{2} m \langle c^2 \rangle = \frac{3}{2} kT$

$\frac{1}{2} \times 1.67 \times 10^{-27} \langle c^2 \rangle = \frac{3}{2} \times 1.38 \times 10^{-23} \times 295$

Root mean square speed = $7.3 \times 10^{6}\ \mathrm{m\,s^{-1}}$

ResultsPlus
Examiner Comments

This candidate is awarded 1 mark.

The chosen equation is correct, but the mass of one proton has been used rather than the mass of 4 nucleons.

(3)

$\frac{1}{2} m \langle c^2 \rangle = \frac{3}{2} kT$

$\frac{1}{2}(1.67\times10^{-27})4 \; \langle c^2 \rangle = \frac{3}{2} 1.38\times10^{-23} \times 295$

$\langle c^2 \rangle = 1.83\times10^{6}\ ms^{-1}$

Root mean square speed = $1.8\times10^{6}\ ms^{-1}$

ResultsPlus
Examiner Comments

This candidate is awarded 2 marks.

The method is correct, but the value of <*c*^{2}> has not been square rooted, despite 'root' mean square appearing in the question and on the answer line.

(3)

$pV = \frac{1}{3} Nm \langle c^2 \rangle$

$m = 4\times1.67\times10^{-27}$

$= 6.68\times10^{-27}$ Kg

$\langle c \rangle = \sqrt{\frac{3pV}{Nm}}$

$= \sqrt{\frac{3(1\times10^{5})(5.13\times10^{-14})}{(1.26\times10^{12})(6.68\times10^{-27})}} =$ ~~1.8×10^8~~ $1.35\times10^{3}\ ms^{-1}$

Root mean square speed = ~~1.8×10^6 ms^-1~~ $1.35\times10^{3}\ ms^{-1}$

ResultsPlus
Examiner Comments

This candidate is awarded 3 marks.

A correct example of the *pV* approach, using values of *V* and *N* from Q18(b)(ii).

(3)

$\frac{1}{2} m \langle c^2 \rangle = \frac{3}{2} kT$

$\frac{1}{2} m \langle c^2 \rangle = \frac{3}{2}(1.38 \times 10^{-23})(22+273) = 6.11 \times 10^{-21}$ J

$\therefore \langle c^2 \rangle = \frac{2(6.11 \times 10^{-21})}{4(1.66 \times 10^{-27})} = 1.84 \times 10^{6}$ m^{2}s^{-2}

$\therefore \sqrt{\langle c^2 \rangle} = \sqrt{1.84 \times 10^{+6}} = 1356.2$ ms^{-1}

Root mean square speed = 1356.2 ms^{-1}

ResultsPlus
Examiner Comments

This candidate is awarded 3 marks.

It is a correct example of the mean kinetic energy approach.

Question 18 (b) (i) - (ii)

Most candidates scored between 4 and 8 marks for these two linked questions.

Q18(b)(i) proved the most straightforward, with the majority gaining all 4 marks. A number of candidates confused decay constant and half-life and a few found it difficult to calculate the number of thorium nuclei in the given mass.

Candidates generally found Q18(b)(ii) more difficult, the most challenging part being the calculation of the number of helium atoms. Candidates did not often appreciate that with such a long half-life, the decay rate would not vary significantly over one year, so they could simply multiply decay rate by time. Many candidates applied the exponential decay equation to the number of thorium nuclei calculated in Q18(b)(i), attempting to calculate the difference in the number after one year. The problem with this was that the number of nuclei was of the order of 10^{17}, whereas the number of decays was of the order of 10^{12}, that is a difference of five orders of magnitude. They therefore had to work to many decimal places in order to obtain a significant difference, which most did not do.

(b) A particular gas mantle contains 5.18×10^{-5} g of thorium-230.

(i) Show that the activity of the thorium-230 in the mantle is about 4.0×10^4 Bq.

230 g of thorium-230 contains 6.02×10^{23} atoms

half-life of thorium-230 = 75 400 years

number of seconds in 1 year = 3.15×10^7

(4)

$\frac{\ln 2}{t_{\frac{1}{2}}} = \lambda$ $\quad \frac{\ln 2}{75400 \times 3.15 \times 10^7} = 2.9 \times 10^{-13}$

$A = \lambda N$

$A = 2.9 \times 10^{-13} \times (6.02 \times 10^{23} \times 2.25 \times 10^{-7})$

$A = 40000$

(ii) Determine the volume of helium gas that could be collected in a year as a result of alpha emission.

Assume that the temperature is 22.0 °C and the pressure is 1.00×10^5 Pa.

(4)

$4 \times 10^4 \times 3.15 \times 10^7 = 1.26 \times 10^{12}$ helium atoms

$pV = NkT$

$V = \frac{NkT}{p}$

$V = \frac{1.26 \times 10^{12} \times 1.38 \times 10^{-23} \times 295}{1 \times 10^5}$

$V = 5.1 \times 10^{-14}$

Volume = 5.1×10^{-14} m^3

ResultsPlus
Examiner Comments

Q18(b)(i) scores 3 marks.

Q18(b)(ii) scores 4 marks.

The calculation is correct in Q18(b)(i), as is the answer, but it has only been quoted to the same number of significant figures as the value in the question. In a 'show that' question, the candidate must demonstrate that the calculation has been carried out by quoting an addiditonal significant figure.

Q18(b)(ii) has been carried out correctly, using the idea that the decay rate can be treated as constant over a period of one year.

(i) Show that the activity of the thorium-230 in the mantle is about 4.0×10^4 Bq.

230 g of thorium-230 contains 6.02×10^{23} atoms

half-life of thorium-230 = 75 400 years

number of seconds in 1 year = 3.15×10^7

(4)

$A = \lambda N$ $\qquad \frac{5.18 \times 10^{-5}}{230} = \frac{N}{6.02 \times 10^{23}}$

$A = \frac{\ln 2}{t_{\frac{1}{2}}} \times N$

~~1.36×10^{17}~~ $1.3558 \times 10^{17} = N$

$75400 \times 3.15 \times 10^7 = 2.38 \times 10^{12}$ Seconds

$A = \frac{\ln 2}{2.38 \times 10^{12}} \times 1.3558 \times 10^{17}$

$A =$ ~~39608~~ 39486 Bq $=$ 4.0×10^4 Bq

(ii) Determine the volume of helium gas that could be collected in a year as a result of alpha emission.

Assume that the temperature is 22.0 °C and the pressure is 1.00×10^5 Pa.

(4)

$pV = NkT$ $\qquad N = N_0 e^{-\lambda t}$

$1 \times 10^5 \times V = N \times 1.38 \times 10^{-23} \times (22 + 273)$

$V = \frac{1 \times 10^{13} \times 1.38 \times 10^{-23} \times (22 + 273)}{1 \times 10^5}$

$N =$ ~~1.36×10^{17}~~ $1.3558 \times 10^{17} \times e^{-\frac{\ln 2}{2.38 \times 10^{12}} \times 3.15 \times 10^7}$

$V = 4.07 \times 10^{-13}$ m^3

$N =$ ~~1.356×10^{17}~~ 1.3557×10^{17}

$1.3558 \times 10^{17} - 1.3557 \times 10^{17} = 1 \times 10^{13}$

Volume = 4.1×10^{-13} m^3

ResultsPlus
Examiner Comments

Q18(b)(i) scores 4 marks.

Q18(b)(ii) scores 2 marks.

Q18(b)(i) is correct and has been awarded full marks.

In Q18(b)(ii), the number of particles has been calculated using the exponentila decay formula. While this has been done to 5 significant figures, that is not sufficient and candidates are expected to realise this. The candidate has been awarded the second and third marking points.

(i) Show that the activity of the thorium-230 in the mantle is about 4.0×10^4 Bq.

230 g of thorium-230 contains 6.02×10^{23} atoms

half-life of thorium-230 = 75 400 years

number of seconds in 1 year = 3.15×10^7

(4)

$A = \lambda N$

$\lambda = \frac{\ln 2}{t_{1/2}} = \frac{\ln 2}{(75400) \times (3.15 \times 10^7)} = 2.92 \times 10^{-13}$

$A = \lambda N$

230 g → 6.02×10^{23} atoms

÷ 4440154

5.18×10^{-5} g → 1.3558×10^{17}

$A = (2.92 \times 10^{-13}) \times (1.3558 \times 10^{17})$

$= 39589.6 = 3.9 \times 10^4 \approx 4.0 \times 10^4$ Bq

(ii) Determine the volume of helium gas that could be collected in a year as a result of alpha emission.

Assume that the temperature is 22.0 °C and the pressure is 1.00×10^5 Pa.

(4)

$pV = NkT$

$V = \frac{NkT}{p} = \frac{(1.36 \times 10^{17})(1.38 \times 10^{-23})(22 + 273)}{1.00 \times 10^5}$

$= 5.537 \times 10^{-9}$

$= 5.5 \times 10^{-9}\ m^3$

Volume = $5.5 \times 10^{-9}\ m^3$

ResultsPlus
Examiner Comments

Q18(b)(i) scores 4 marks.

Q18(b)(ii) scores 2 marks.

Q18(b)(i) is correct for full marks.

The value of *N* from Q18(b)(i) has been used in part Q18(b)(ii), so the answer is incorrect. Marking points 2 and 3 have been allowed for 'use of' the relevant formulae, but this has not been treated as error carried forward so no more marks are available.

Paper Summary

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

- Ensure you know the command words and understand the level of required response for each of them, eg 'evaluate' requires a judgement supported by evidence which may involve some calculation.
- Where you are asked to come to a conclusion by command words such as ‘determine whether’ or ‘deduce whether’ using numerical data, you must complete your calculations, explicitly compare the relevant values and then make a clear statement in conclusion – ‘calculate, compare, conclude’.
- Check that quantitative answers represent sensible values and go back over calculations when they do not.
- Learn standard descriptions of physical processes, such as the production of atomic line spectra or standing waves, and be ready to apply them with sufficient detail to specific situations; identifying the necessary explanation for the context, in order to answer the specific question set.
- In questions with mixed quantities, be sure to convert all values to standard SI base units or derived units, eg convert years or days to seconds and °C to K for gases.
- Be sure to know the standard SI prefixes and be able to apply the correct power of ten.
- Physical quantities have a magnitude and a unit and both must be given in answers to numerical questions.
- When substituting in an equation with a power term, eg ω^2, don’t suddenly miss off the index when substituting or forget it in the calculation, for example, by failing to calculate a square root.
- Whenever you are given the diameter of a circle or sphere, consider it carefully to decide whether you need to use the radius or the diameter in the following calculations.

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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