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Examiners' Report
June 2018

GCE Physics 9PH0 02

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Introduction

This was the second sitting of this examination for the new specification. The assessment structure of Advanced 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. Question 16 assessed the ability to structure answers logically while questions 12(a), 13(c), 15(a)(i) and 19(a)(ii) all required a deduction or judgement with justification of the conclusion, as described in Assessment Objective 3 (AO3). Students generally responded well to these, showing some ingenuity in the variety of approaches, although the conclusions were not always made sufficiently explicit and so the final mark was not always awarded.

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

Students at the lower end of the range could complete calculations involving simple substitution and limited rearrangement, including structured series of calculations, but could not always tackle calculations involving several steps or other complications, such as converting years to seconds. They also knew some significant points in explanations linked to standard situations, such as the use of the stellar parallax method for determining astronomical distances, but 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 they scored much more highly on Assessment Objective 1 than on Assessment Objectives 2 and 3.

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 and most points were included in ordered explanations of the situations in the questions.

Question 11 (a)

Most students made a good start to the question, equating the given expressions and arriving at ½ $m \langle c^2 \rangle = 3/2\ kT$. Many did not go on to state that k is constant, which was required to establish proportionality for the second mark. ½ $m \langle c^2 \rangle$ was accepted for mean kinetic energy without comment, but students deriving an expression for $\langle c^2 \rangle$ needed to establish its relationship to kinetic energy, which rarely happened.

11 (a) For an ideal gas $pV = NkT$ and $pV = \frac{1}{3} Nm \langle c^2 \rangle$.

Use these relationships to show that the mean kinetic energy of a gas molecule is proportional to the absolute temperature.

(2)

$pV = NkT$

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

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

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

$3kT = m \langle c^2 \rangle$

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

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Examiner Comments

The algebraic manipulation is correct and mean kinetic energy has been identified, but there is no reference to constants, so 1 mark is awarded.

11 (a) For an ideal gas $pV = NkT$ and $pV = \frac{1}{3} Nm \langle c^2 \rangle$.

Use these relationships to show that the mean kinetic energy of a gas molecule is proportional to the absolute temperature.

(2)

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

$\frac{3}{2} NkT = \frac{N m \langle c^2 \rangle}{2}$

$\frac{3}{2} kT = \frac{m \langle c^2 \rangle}{2}$ $\quad T \propto \langle c^2 \rangle$

ResultsPlus
Examiner Comments

The correct final equation is obtained. This is restated as a proportionality expression but without stating that k is constant and losing the mean kinetic energy formula so, again, this merits one mark.

11 (a) For an ideal gas $pV = NkT$ and $pV = \frac{1}{3}Nm<c^2>$.

Use these relationships to show that the mean kinetic energy of a gas molecule is proportional to the absolute temperature.

(2)

$NkT = \frac{1}{3}Nm<c^2>$

$\times 3/2$

$\frac{3}{2}kT = \frac{1}{2}m<c^2>$

k is a constant

$\therefore$ as $\frac{1}{2}m<c^2>$ = Mean Kinetic energy

$T \propto KE$

ResultsPlus
Examiner Comments

2 marks for a correct answer, identifying mean kinetic energy and stating that k is constant.

Question 11 (b)

Students generally substituted the given values, converting to absolute temperature, and calculated $<c^2>$. A surprisingly large proportion, however, stopped there and did not take the square root. There appeared to be widespread lack of awareness of what 'root-mean-square' means.

(b) The molecules in a sample of gas have a mass of 5.0×10^{-26} kg.

Calculate the root-mean-square speed of gas molecules in the gas at 25 °C.

(3)

~~$c_{rms} = \sqrt{\frac{5 \times 10^{-26}}{298}}$~~

$\frac{1}{2} m <c^2> = \frac{3}{2} kT$

$\frac{1}{2} \times 5.0 \times 10^{-26} <c^2> = \frac{3}{2}(1.38 \times 10^{-23}) 298)$

$<c^2> = \dfrac{\frac{3}{2}(1.38 \times 10^{-23}) 298}{\frac{1}{2}\, 5.0 \times 10^{-26}}$

$<c^2> = 246744 \text{ ms}^{-1}$

Root-mean-square speed = 246744 ms^{-1}

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Examiner Comments

The substitution is correct and so is the calculation, as far as it goes, but the student appears to think that $<c^2>$ is root-mean-square speed. 2 marks are awarded.

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Examiner Tip

Be careful when a formula uses squares to either square or square root the quantity as appropriate.

(b) The molecules in a sample of gas have a mass of 5.0 × 10^{-26} kg. m

Calculate the root-mean-square speed of gas molecules in the gas at 25 °C.

(3)

$T = 25 + 273 = 298\ K$

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

$\Rightarrow \frac{1}{2} \times 5.0 \times 10^{-26} \times \langle c^2 \rangle = \frac{3}{2} \times 1.38 \times 10^{-23} \times 298$

$2.5 \times 10^{-26} \langle c^2 \rangle = 6.1686 \times 10^{-21}$

$\langle c^2 \rangle = 246744$

$c_{rms} = \sqrt{\langle c^2 \rangle} = \sqrt{246744} = 497\ ms^{-1}$

Root-mean-square speed = $497\ ms^{-1}$

ResultsPlus
Examiner Comments

Full marks for a correct calculation and answer.

Question 12 (a)

Wien’s law was used for a calculation straightforwardly by most students, but instead of using a temperature typical for the scene to determine a peak wavelength which could be compared to the stated wavelength to draw a conclusion, many used the stated wavelength to determine a peak temperature of 4140 K. This could still be used to draw a conclusion related to a stated lower temperature, but there was a lack of understanding of the inverse relationship of wavelength and temperature in Wien’s law and said instead that at temperatures below 4140 K the wavelength would be shorter.

(a) Deduce whether the objects shown in the photographs would be expected to have peak emissions at infrared wavelengths. Your answer should include a calculation.

(4)

longest wavelength of visible red light ≈700 nm

$$T = \frac{2.898 \times 10^{-3}}{700 \times 10^{-9}}$$

$= 4140$ k.

No as the the temperature of the objects would have to be at 4140k which is a lot higher than the actual value.

ResultsPlus
Examiner Comments

A correct use of Wien's law, but an inappropriate conclusion showing a lack of actual understanding of the relationship between temperature and peak wavelength. This is awarded 2 marks.

(a) Deduce whether the objects shown in the photographs would be expected to have peak emissions at infrared wavelengths. Your answer should include a calculation.

(4)

longest wavelength of visible red light ≈700 nm

Wein's Law : $\lambda_{max} T = 2.898 \times 10^{-3}$

where λ_{max} is the peak wavelength and T is the temperature.

$\lambda_{max} = \frac{2.898 \times 10^{-3}}{298} = 9.7 \times 10^{-6}$ m

$= 9.7 \times 10^{3}$ nm which is alot greater than longest visible red light so it will have peak emission at infrared wavelength.

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Examiner Comments

Full marks awarded for a correct calculation using an appropriate temperature and a suitable comparison in conclusion.

Question 12 (b)

Most of the responses included reference to reflection, although many incorrectly introduced the idea of total internal reflection. Fewer mentioned that infrared at these wavelengths wasn't transmitted and many deduced that it was absorbed although there wasn't sufficient evidence for this conclusion as the lack of transmission could be solely due to reflection.

State what can be concluded about glass and infrared radiation.

(2)

Glass totally internally reflects infrared radiation, and infrared radiation isn't able to pass through the glass.

ResultsPlus
Examiner Comments

This answer is awarded 1 mark for stating that the infrared radiation is unable to pass through the glass. The reference to total internal reflection is incorrect.

State what can be concluded about glass and infrared radiation.

(2)

Glass does not allow infrared radiation to travel through it. Infrared radiation is reflected by glass.

ResultsPlus
Examiner Comments

Full marks for a correct answer.

Question 13 (a)

Students were generally able to state the relationship between the Stokes' law force and weight, although some complicated things for themselves by not following the instruction to ignore upthrust. They usually used the formula for a sphere and were able to arrive at the required expression, but there was occasional confusion between the symbols *V* and *v* and some did not recall the correct formula for the volume of a sphere.

13 Raindrops of different sizes fall with different terminal velocities through air.

The table shows the measured value of the terminal velocity for raindrops of different sizes.

Raindrop size	**Drop diameter / mm**	**Terminal velocity / m s^{-1}**
small	0.5	2.1
medium	2.0	6.5
large	5.0	9.1

(a) Derive, using Stokes' law, the following expression for the terminal velocity *v* of a spherical raindrop in terms of its radius *r*.

$$v = \frac{2g\rho r^2}{9\eta}$$

where ρ is the density of rainwater and η is the viscosity of air.

You should ignore upthrust.

(2)

$F = 6\pi\eta rV$ $\rho = \frac{m}{V}$ so $m = \rho V$ $F = gm$

$gm = 6\pi\eta rV$

$g\rho V = 6\pi\eta rV$

ResultsPlus
Examiner Comments

This gets a bit beyond stating that upward force is equal to weight, but the formula for a sphere has not been used, so the student is unable to complete the question (1 mark).

13 Raindrops of different sizes fall with different terminal velocities through air.

The table shows the measured value of the terminal velocity for raindrops of different sizes.

Raindrop size	**Drop diameter / mm**	**Terminal velocity / m s^{-1}**
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(a) Derive, using Stokes' law, the following expression for the terminal velocity v of a spherical raindrop in terms of its radius r.

$$v = \frac{2g\rho r^2}{9\eta}$$

where ρ is the density of rainwater and η is the viscosity of air.

You should ignore upthrust.

(2)

Stokes Law : $F = 6\pi r\eta v$

$6\pi r\eta v = \rho\, 4/3\, \pi r^3 g$

$3\,6\pi r\eta v = \rho\, 4/3\, \pi r^3 g$

$v = \dfrac{2g\rho r^2}{9\rho}$

weight $= mg$

$= \rho V g$

$= \rho \times \frac{4}{3} \pi r^3 g$

ResultsPlus
Examiner Comments

This is an example of a fully correct response gaining 2 marks.

Question 13 (b)

This was completed with little difficulty and incorrect responses were very rare. The most common errors were to use diameter instead of radius or failing to square the radius when calculating the answer.

(b) Show that the expression given in (a) produces a value of about 800 m s^{-1} for the terminal velocity of a large raindrop.

(2)

$\rho = 1.0 \times 10^3$ kg m^{-3}
$\eta = 1.8 \times 10^{-5}$ Pa s

$$V = \frac{2g\rho r^2}{9\eta} = \frac{2 \times 9.81 \times 1 \times 10^3 \times (5 \times 10^{-3})^2}{9 \times 1.8 \times 10^{-5}}$$

$$= 302.8 \text{ ms}^{-1}$$

ResultsPlus
Examiner Comments

In this response diameter has not been halved to find radius. There is an error in the calculation as well because this answer is a tenth of what these figures should produce. 1 mark awarded for using the formula with relevant quantities.

(b) Show that the expression given in (a) produces a value of about 800 m s^{-1} for the terminal velocity of a large raindrop.

(2)

$\rho = 1.0 \times 10^3$ kg m^{-3}
$\eta = 1.8 \times 10^{-5}$ Pa s

$$V = \frac{2g \times 1 \times 10^3 \times (5 \times 10^{-3})^2}{9(1.8 \times 10^{-5})} = 800 \text{ ms}^{-1}$$

ResultsPlus
Examiner Comments

This student used radius and then changed it to diameter. The calculated answer should therefore have been 4 times too big, but they have written the required answer from the question. When a question starts with 'show that' and states a quantity, we require full substitution and an answer given to at least one more significant figure than the question to prove that it has actually been calculated. 1 mark

ResultsPlus
Examiner Tip

In 'show that' questions, state the answer to one more significant figure than the given quantity.

(b) Show that the expression given in (a) produces a value of about 800 m s^{-1} for the terminal velocity of a large raindrop.

(2)

$\rho = 1.0 \times 10^3$ kg m^{-3}
$\eta = 1.8 \times 10^{-5}$ Pa s

$v = \frac{2 \times 9.81 \times 10^3 \times (2.5 \times 10^{-3})^2}{9 \times 1.8 \times 10^{-5}}$

$= 757 \text{ ms}^{-1}$

$\approx 800 \text{ ms}^{-1}$

ResultsPlus
Examiner Comments

Full marks for a correct answer.

Question 13 (c)

Students demonstrated their knowledge and understanding of the conditions of Stokes' law, but could not always apply these to draw a conclusion as required by this question. Many set out the conditions in detail but did not make it clear whether they applied or not in this situation. They rarely referred to the key piece of evidence, the factor of almost 100 between their calculated value from part (b) and the measured value in table, which should have put it beyond doubt.

(c) Explain whether Stokes' law is suitable for calculating the terminal velocity of raindrops.
(3)

Stokes's law is only suitable for calculating terminal velocity when there small molecules (objects) ~~has a small mass~~ being used and small masses, as laminar flow is required for terminal velocity. The Stokes's law is suitable for raindrops as they are small and have a small masses. However, air resistance and rainfall can create turbulent flow so that will affect the calculation for its terminal velocity.

ResultsPlus
Examiner Comments

This response incorrectly states that Stokes' law is suitable, but then goes on to give a reason, turbulent flow, why it is not suitable (0 marks).

(c) Explain whether Stokes' law is suitable for calculating the terminal velocity of raindrops.
(3)

Stokes law isn't suitable because it gives a large difference to the measured value given in the table. The measured terminal velocity was 9.1 ms^{-1} but we calculated ~~[illegible]~~ 75, which has a large percentage difference. There must ~~have~~ be some external influences or other forces acting on the raindrop that Stokes law hasn't accounted for.

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Examiner Comments

A correct conclusion using the data is obtained, but there is no discussion of the physical factors. The question says 'explain' so, in addition to quoting the numerical evidence, reasons for why this is the case should be given in some detail - not just 'external forces' (1 mark).

ResultsPlus
Examiner Tip

Be sure to be aware of the requirements indicated by the different command words.

(c) Explain whether Stokes' law is suitable for calculating the terminal velocity of raindrops.
(3)

- Stoke's law for spherical objects, raindrops are not perfectly spherical.
- Stoke's law is for spherical objects moving at low speeds ⇒ since speed of raindrops ($757\ ms^{-1}$) is very high, not suitable.
- Flow around raindrop is not always laminar, there can be turbulent flow.
- So not suitable.

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Examiner Comments

The physical reasons are given in terms of Stokes' law. There is some misunderstanding of the situation because the calculated speed is stated as if it is the actual speed. A comparison between calculated and measured speed is required for a third mark (2 marks).

(c) Explain whether Stokes' law is suitable for calculating the terminal velocity of raindrops.

(3)

~~From the~~ the value calculated above (800 m/s) differs a lot from the value in table (9.1 m/s)
The stokes' law ~~only~~ only applies for a perfect sphere in a perfect laminar flow. NOT in a turbulent flow.
The rain drop is not a perfect sphere and there is a significant amount of turbulent flow resisting its motion so the Stokes' law cannot be applied.
∴ NOT suitable.

(Total for Question 13 = 7 marks)

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Examiner Comments

A very good response awarded 3 marks.

Question 14

The marks here were equally divided between a calculation, using the energy to calculate momentum and then the relationship between the de Broglie wavelength and momentum, and an explanation of the interference observed. Students very often only addressed one of these and therefore did not make the connection between the calculated wavelength and the observed effect.

Of those completing a calculation, many used the quoted wavelength to calculate the energy instead.

Of those explaining interference, some did so in general terms and did not clearly link X to destructive interference and Y to constructive interference. Others got path difference and phase difference confused, saying that the phase difference was half a wavelength, for example, rather than saying that the path difference was half a wavelength.

The path difference for electrons arriving at band X from the separate slits was 2.5×10^{-11} m. For electrons arriving at band Y the path difference was 5.0×10^{-11} m.

Explain why this pattern is observed when the electron energy is 9.6×10^{-17} J.

The electrons are travelling at non-relativistic speeds.

(6)

- As the electrons travel through the double slit they act as waves so superpose and interfere.
- If the path difference is a whole number of wavelengths, they are in phase so they ~~superpo~~ constructively interfere causing areas of maximum amplitude such as at Y. This suggests that ~~the~~ one wavelength is 5.0×10^{-11} m and a multiple of it for any areas of maxima
- If the path difference is $(n+\frac{1}{2})\lambda$, the waves are in antiphase so they destructively interfere causing areas of minimum amplitude such as at X. The ~~[illegible]~~ path difference was 2.5×10^{-11} m which is half a wavelength.

ResultsPlus
Examiner Comments

This answers the interference part correctly but doesn't include any calculation related to the wavelength (3 marks).

The path difference for electrons arriving at band X from the separate slits was 2.5×10^{-11} m. For electrons arriving at band Y the path difference was 5.0×10^{-11} m.

Explain why this pattern is observed when the electron energy is 9.6×10^{-17} J.

The electrons are travelling at non-relativistic speeds.

(6)

$E_k = \frac{1}{2}mv^2 \Rightarrow \sqrt{\frac{2E}{m_e}} = v = 1.45 \times 10^7 \, ms^{-1}$

$\lambda = \frac{h}{p} = \frac{6.63 \times 10^{-34}}{1.45 \times 10^7 \times 9.11 \times 10^{-31}} = 5 \times 10^{-11} \, m$

These patterns are observed because the de Broglie wavelength equation can be used to find these patterns. This equation links the momentum of a particle with its wavelength and given the energy of the particle its wavelength must be 5×10^{-11} m as calculated. The reduction in path difference is due to the dispersion of electrons as they get further from the central maxima.

ResultsPlus
Examiner Comments

3 marks were awarded here for the calculations, but the written part does not explain the interference effect observed.

The path difference for electrons arriving at band X from the separate slits was 2.5×10^{-11} m. For electrons arriving at band Y the path difference was 5.0×10^{-11} m.

Explain why this pattern is observed when the electron energy is 9.6×10^{-17} J.

The electrons are travelling at non-relativistic speeds.

(6)

when electron energy is 9.6×10^{-17}, $E_K = \frac{1}{2}mv^2$.

~~[illegible]~~

~~Since $\lambda = \frac{h}{p}$ and $v = f\lambda$~~

$v = \sqrt{\frac{2E_K}{m}}$, $v = \sqrt{\frac{2 \times 9.6 \times 10^{-17}}{9.11 \times 10^{-31}}}$

$v = 1.45 \times 10^{7}$ since $\lambda = \frac{h}{p}$, $\lambda = \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \times 1.45 \times 10^{7}}$

$\therefore \lambda = 5.0 \times 10^{-11}$ m.

at point X, the path difference of the two waves of electrons is equal to half of the wavelength of the electrons. This means the waves will meet in antiphase & undergo destructive interference when they superpose. This leaves zero/minimum intensity at band X so no electrons are detected here.

At band Y, the electrons meet with a path difference equal to 1 wavelength so they undergo constructive interference when they superpose as they meet in phase. This leaves a high intensity at band Y.

(Total for Question 14 = 6 marks)

ResultsPlus Examiner Comments

The full 6 marks have been awarded to this response which includes a full, correct calculation and the required explanation of the interference effect.

Question 15 (a) (i)

Students adopted different approaches to this question. The most straightforward was to calculate the period and compare it to 12 hours. An alternative approach was to use the period to calculate the orbital height, although here some forgot to subtract the radius of the planet. The other methods involved calculating the same quantity from two different starting points – the stated period and the orbital height – to arrive at comparable quantities. Students doing this often failed to make an explicit final comparison to make their conclusion clear and were not awarded the final mark.

In their calculations, students were generally able to apply Newton's universal law of gravitation correctly, but could not always proceed successfully from there. Using the correct value of separation by adding the orbital height and planetary radius was a source of difficulty for a number of students.

15 In 2015 the Messenger spacecraft crashed into the surface of the planet Mercury after four years in orbit observing the surface of Mercury.

Messenger's orbit was highly elliptical, varying between 200 km and 15 000 km above the surface of Mercury. Messenger completed one full orbit every 12 hours.

mass of Messenger spacecraft = 565 kg
mass of planet Mercury = 3.30×10^{23} kg
radius of planet Mercury = 2430 km

(a) It has been suggested that the same orbital period of about 12 hours could have been achieved if Messenger was in a circular orbit 7690 km above the surface of Mercury.

(i) Determine whether this suggestion is correct.

(4)

$m r \omega^2 = \frac{GmM}{r^2} \Rightarrow \left(\frac{2\pi}{T}\right)^2 = \frac{GM}{r^3} \Rightarrow \frac{4\pi^2}{T^2} = \frac{GM}{r^3}$

$\frac{T^2}{4\pi^2} = \frac{r^3}{GM} \rightarrow T^2 = \frac{4\pi^2 r^3}{GM}$

$T^2 = \frac{4\pi^2 \times (7690 \times 10^3)^3}{6.67 \times 10^{-11} \times 3.3 \times 10^{23}}$

$T = 28559\text{ s} = 7.93$ hours.

→ Suggestion is incorrect.

ResultsPlus
Examiner Comments

In this response the relevant formulae have been combined before substitution. An incorrect value for *r* has been used, ignoring the planetary radius, so the 'use of' marks have been awarded, but not the mark for the final answer. There is a correct conclusion based on the value obtained, but it has not been compared directly with 12 hours, so the final mark is not awarded, giving a total mark of 2.

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Examiner Tip

When you are asked to 'determine whether' certain conditions are met, you must make a clear statement, including any values being compared.

15 In 2015 the Messenger spacecraft crashed into the surface of the planet Mercury after four years in orbit observing the surface of Mercury.

Messenger's orbit was highly elliptical, varying between 200 km and 15 000 km above the surface of Mercury. Messenger completed one full orbit every 12 hours.

T.

mass of Messenger spacecraft = 565 kg
mass of planet Mercury = 3.30×10^{23} kg
radius of planet Mercury = 2430 km

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

(a) It has been suggested that the same orbital period of about 12 hours could have been achieved if Messenger was in a circular orbit 7690 km above the surface of Mercury.

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

(i) Determine whether this suggestion is correct. **(4)**

2430 + 7690

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

$F = \frac{GMm}{r^2} = \frac{mv^2}{r} \quad \frac{GM}{r} = v^2. \quad v^2 = (\omega r)^2 = \frac{4\pi^2 r^2}{T^2}$

$\frac{GM}{r} = \frac{4\pi^2 r^2}{T^2} \quad T = \sqrt{\frac{4\pi^2 r^3}{GM}}$

$\therefore T = \sqrt{\frac{4\pi^2 \times [(2430+7690)\times 10^3]^3}{6.67\times 10^{-11}\,Nm^2kg^{-2} \times 3.3\times 10^{23}}} = 4.31\times 10^4\,s$

$\frac{4.31\times 10^4}{60\times 60} = 12.0$ hours.

12.0 = 12.0 ∴ this suggest is correct.

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Examiner Comments

4 marks out of 4 awarded for the correct calculation of the answer and a correct conclusion including a direct comparison of the values.

Question 15 (a) (ii)

Students displayed some understanding of relevant advantages, but did not always express this with sufficient clarity to be awarded two marks. 'Better pictures' would not be sufficient.

(ii) The elliptical orbit chosen had advantages over this circular orbit.

Explain one advantage.

(2)

Gets closer to the planet at certain points so observations are better.

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Examiner Comments

1 mark has been awarded for stating that the satellite can get closer to the planet than in the circular orbit, but 'observations are better' is not sufficient for a further mark.

(ii) The elliptical orbit chosen had advantages over this circular orbit.

Explain one advantage.

(2)

It could come alot closer to ~~mercus~~ Mercury at given times meaning any photos it took would be alot more detailed

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Examiner Comments

In this response the comment that photographs would be a lot more detailed was just sufficient for the award of the second mark for a total of 2.

Question 15 (b)

This was poorly answered except at the higher levels of achievement for the paper. The great majority of students seemed entirely unfamiliar with the concept of gravitational potential, something that was not in the previous specification. Many did not even appreciate the change in gravitational field strength as the distance from the planet increased and simply used Newton's universal law of gravitation to calculate a single value of acceleration due to free fall and applied this using equations of motion.

Of those using gravitational potential, some had difficulty in applying the correct distances or used a single distance and did not calculate a change.

(b) Calculate the velocity an object would have as it reached the surface of Mercury if it was released from Messenger's maximum orbital height.
Assume the object is released from rest and that Mercury has no atmosphere.

(4)

$15000 \times 10^3 = h$

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

~~$g = \frac{6.67 \times 10^{-11} \times 565}{(15000 \times 10^3)^2} = 1.67 \times 10^{-72}$~~

Average g $\quad g = \frac{6.67 \times 10^{-11} \times 3.3 \times 10^{23}}{(7500 \times 10^3)^2}$ ~~6.6996 × 10^[illegible] Nm^{-2}~~ $= 0.39 ms^{-2}$

~~mg =~~ $mgh = \frac{1}{2}mv^2$

$\sqrt{15000 \times 10^3 \times 0.39 \times 2} = v = 3426 ms^{-1}$

Velocity = 3426 ms^{-1}

ResultsPlus
Examiner Comments

This response was allowed 1 mark, marking point 3 on the mark scheme, for using the idea of a transfer of energy from the gravitational potential energy store to the kinetic energy store. The student has calculated a single value of gravitational field strength and incorrectly applied this throughout the whole distance and has gained no further marks.

(b) Calculate the velocity an object would have as it reached the surface of Mercury if it was released from Messenger's maximum orbital height.
Assume the object is released from rest and that Mercury has no atmosphere.

(4)

Gravitational potential difference = $-GM\left(\frac{1}{r_2} - \frac{1}{r_1}\right)$

$= -GM\left(\frac{1}{2430000} - \frac{1}{2430000 + 15000000}\right) = -7.8 \times 10^6$ J/kg

change in gravitational potential energy = 565 kg × -7.8×10^6 = -4.4×10^9 J

= increase in kinetic energy = $\frac{mv^2}{2}$

$v = \sqrt{\frac{2}{m} \times 4.4 \times 10^9}$

= 3948 m/s

= 3900 m/s

Velocity = 3900 m/s

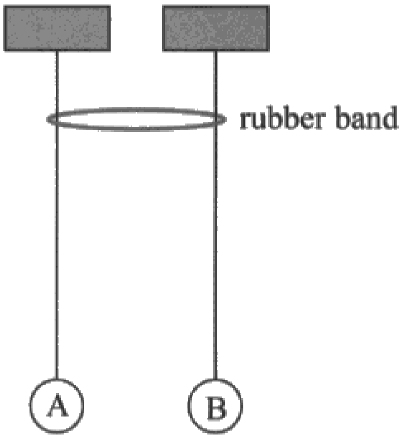
ResultsPlus
Examiner Comments

The full 4 marks have been awarded for this answer where the difference in gravitational potential has been correctly calculated and used to arrive at the required answer.

Question 16 (a)

Many students did not see this as an example of resonance and expressed their answers in terms of damping. They all, at least, appreciated that a transfer of energy was taking place and, as long as they were careful to identify and address the three main phases of the behaviour described, were rewarded for describing the process of transfer from B to A. For those describing resonance, a statement linking equal lengths to equal natural frequencies was often missing as was the idea that all of A’s energy had been transferred to B at one stage. Similarly, the difference in length in the last part was not always directly linked to a difference in natural frequencies.

16 The diagram shows two identical pendulums, A and B, side by side with a rubber band placed over both strings.



Pendulum A is displaced and starts to oscillate. As pendulum A oscillates, pendulum B starts to oscillate with the same time period, its amplitude increasing as the amplitude of pendulum A decreases. At one stage pendulum A is no longer oscillating and pendulum B has its maximum amplitude. Then pendulum A starts to oscillate again with increasing amplitude, as the amplitude of pendulum B decreases.

The apparatus is adjusted so that the pendulums do not have the same length as each other. When the first pendulum is set into oscillation, the second pendulum starts to oscillate, but with very small amplitude; the first pendulum does not stop oscillating.

*(a) Explain this behaviour.

(6)

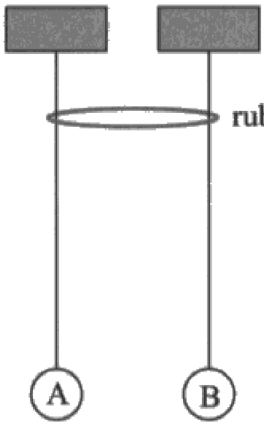
Initially pendulum A's oscillations pull the rubber band at the same frequency as pendulum B's natural frequency. The pull of the rubber band acts as a driving force with driving frequency the same as the natural frequency of pendulum B. Pendulum B undergoes forced oscillations. The same frequencies cause resonance of pendulum B, thus the increasing amplitude.

The rubber band causes pendulum A to undergo damped oscillations, removing energy from the system and thus reducing its amplitude.

ResultsPlus
Examiner Comments

Indicative marking points 2 and 3 have been included in the first paragraph, allowing 2 marks. This is insufficient indicative content for the award of marks for linkage, so the total mark is 2.

16 The diagram shows two identical pendulums, A and B, side by side with a rubber band placed over both strings.



Pendulum A is displaced and starts to oscillate. As pendulum A oscillates, pendulum B starts to oscillate with the same time period, its amplitude increasing as the amplitude of pendulum A decreases. At one stage pendulum A is no longer oscillating and pendulum B has its maximum amplitude. Then pendulum A starts to oscillate again with increasing amplitude, as the amplitude of pendulum B decreases.

The apparatus is adjusted so that the pendulums do not have the same length as each other. When the first pendulum is set into oscillation, the second pendulum starts to oscillate, but with very small amplitude; the first pendulum does not stop oscillating.

*(a) Explain this behaviour.

(6)

This is an example of resonance. ~~Pendulum when~~ Pendulum A begins to oscillate at its natural frequency, which, because they have the same length, is also the natural frequency of pendulum B. Pendulum B is therefore forced to oscillate at its natural frequency so there is resonance where B has an increasing amplitude and there is a maximum energy transfer from A to B. Pendulum A stops oscillating when all of its energy have been transferred to B. A begins to oscillate again when B forces it to oscillate at its natural frequency so resonance and maximum energy transfer occurs. When they have different lengths they have different natural frequencies so A pendulum A still forces B into oscillation but it does not oscillate at its natural frequency so resonance does not occur. No maximum amplitude or maximum energy transfer so A does not transfer all energy

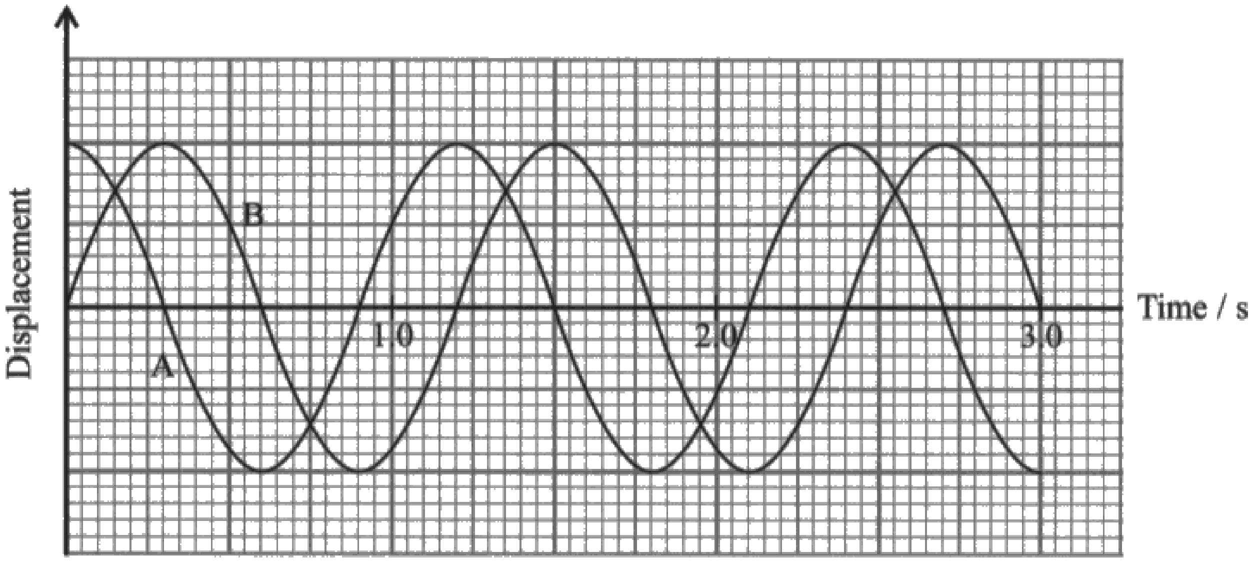
ResultsPlus
Examiner Comments

All 6 of the indicative marking points have been included, allowing 4 marks for the indicative content. As required for maximum linkage marks, the answer shows a coherent and logical structure with linkages and fully sustained lines of reasoning demonstrated throughout, so the total mark is 6.

Question 16 (b) (i)

This mark was very rarely awarded. Most students could identify the phase difference as π/2 but they just did not make any mention of which was ahead of which in the cycle.

(b) The graph shows how the displacement of each pendulum varies with time at one stage in the motion.



(i) State the phase relationship between the two pendulums.

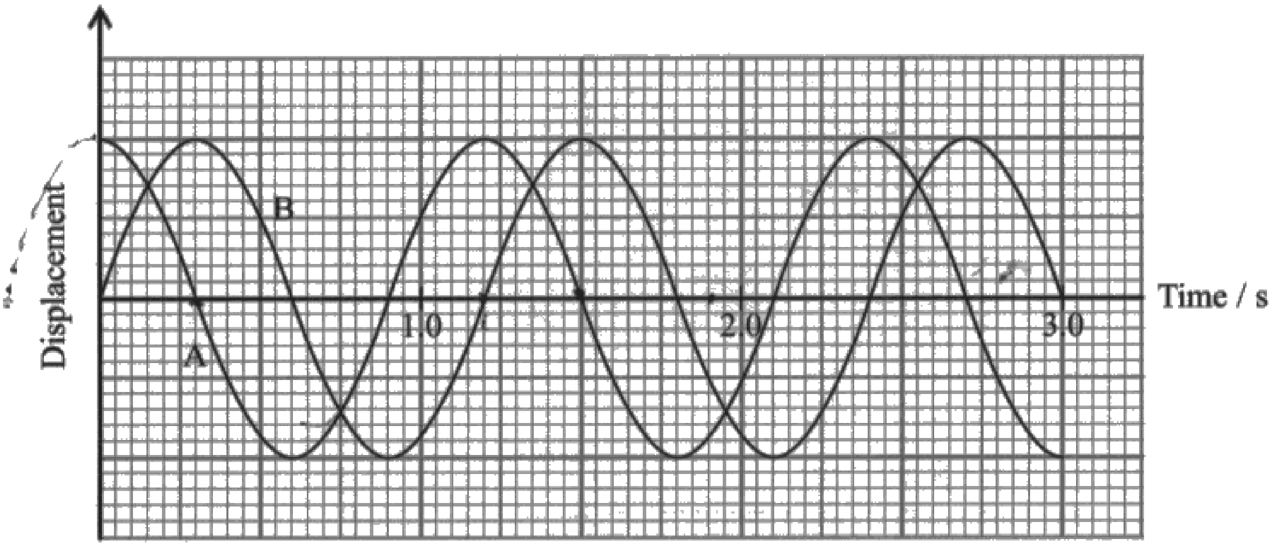
(1)

90° – difference of phase – out of phase

ResultsPlus
Examiner Comments

A phase difference of 90 degrees has been correctly identified, but no information about which pendulum leads to fully describe the phase relationship, so no marks were awarded.

(b) The graph shows how the displacement of each pendulum varies with time at one stage in the motion.



(i) State the phase relationship between the two pendulums.

(1)

B is π/2 ahead of A

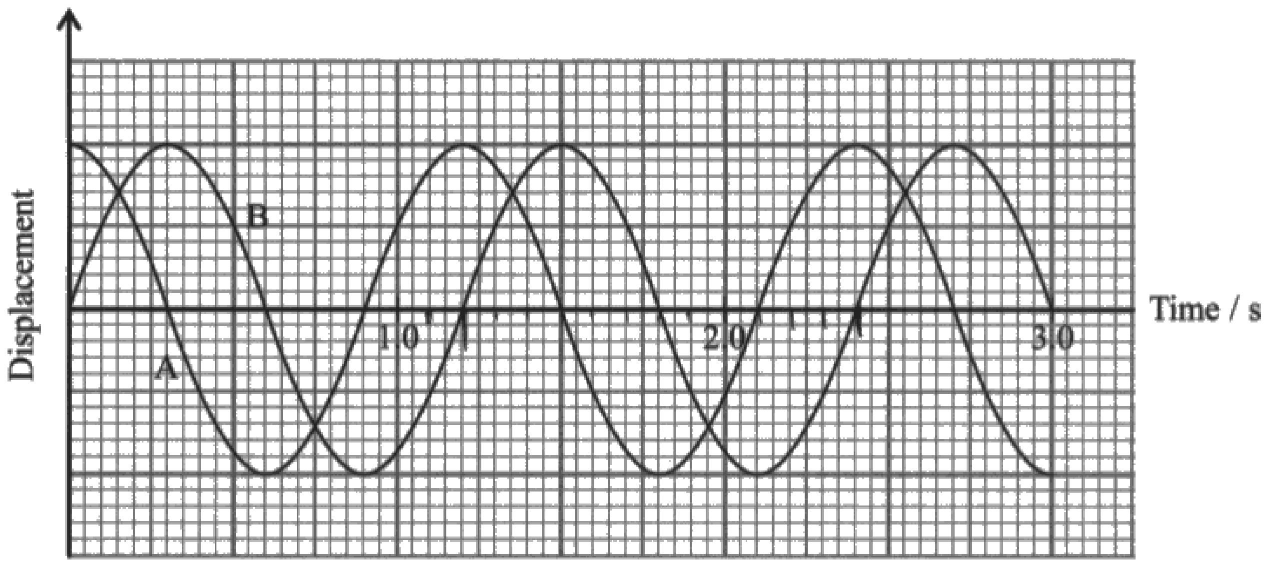
ResultsPlus
Examiner Comments

No mark awarded. The phase difference of π/2 is correct, but this response states that B leads. On the graph A is at maximum displacement at time 0s but B is not at maximum displacement until a later time, so A leads B. A graph of this shape for two waves with distance as the horizontal axis would show B ahead of A, but not this graph.

ResultsPlus
Examiner Tip

When considering phase differences, look carefully to check whether the horizontal axis shows time or distance.

(b) The graph shows how the displacement of each pendulum varies with time at one stage in the motion.



(i) State the phase relationship between the two pendulums.

(1)

A is $\frac{\pi}{2}$ radians ahead of B.

ResultsPlus

Examiner Comments

1 mark for a correct answer.

Question 16 (b) (ii)

Most students applied the relevant formula to arrive at the correct answer, but a number misread the graph and used an incorrect value of time. Some students, in obtaining the time period of pendulum B, read 1.0 on the graph and counted 4 small squares to give a time of 1.4 s instead of 1.2 s because they did not look beyond the 1.0 to correctly establish the scale.

(ii) [redacted]

(3)

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

$l = \left(\frac{T}{2\pi}\right)^2 \times g = \left(\frac{1.4}{2\pi}\right)^2 \times 9.81 = 0.487\text{m}$

$= 0.49\text{m}$

Length = 0.49 m

ResultsPlus
Examiner Comments

1 mark has been awarded for 'use of' the correct formula with relevant quantities, but the time used is incorrect, so no more marks are available.

ResultsPlus
Examiner Tip

When using graphs, read the scale values on either side of the point of interest to ensure you are using the scale correctly.

(ii) Determine the length of pendulums A and B.

(3)

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

$1.2s = 2\pi\sqrt{\frac{L}{g}}$

$0.1909... = \sqrt{\frac{L}{g}}$

$0.437... = \frac{L}{g}$

$L = 4.287m$

Length = 4.287m

ResultsPlus
Examiner Comments

1 mark has been awarded for using the correct time from the graph, but there is no mark for substitution because the numerical value for *g* has not been written down.

ResultsPlus
Examiner Tip

'Use of' marks cannot be awarded if physical constants are left as letters - they must be written down as the correct numerical value.

Question 17 (a)

This was the first scale ray diagram in the examination of Advanced level on this specification and it was not answered well by the majority. The question made clear that the screen shown was the object in this diagram, and that seemed to have been understood, but the basic use of two correct construction rays extrapolated to a virtual image was not seen in over a half of responses. Students completing the ray diagram were usually within the accuracy limits and could often calculate magnification, but a clear conclusion related to the conditions set out was not often made by those who had completed everything else correctly in this AO3 question.

For a particular user of the headset, the image of the screen must be at least 16 cm from the eye and have a magnification of at least 3.0.

Determine whether this would be possible with a lens of focal length 3.8 cm. Your answer should include a full-scale ray diagram drawn on the grid provided.

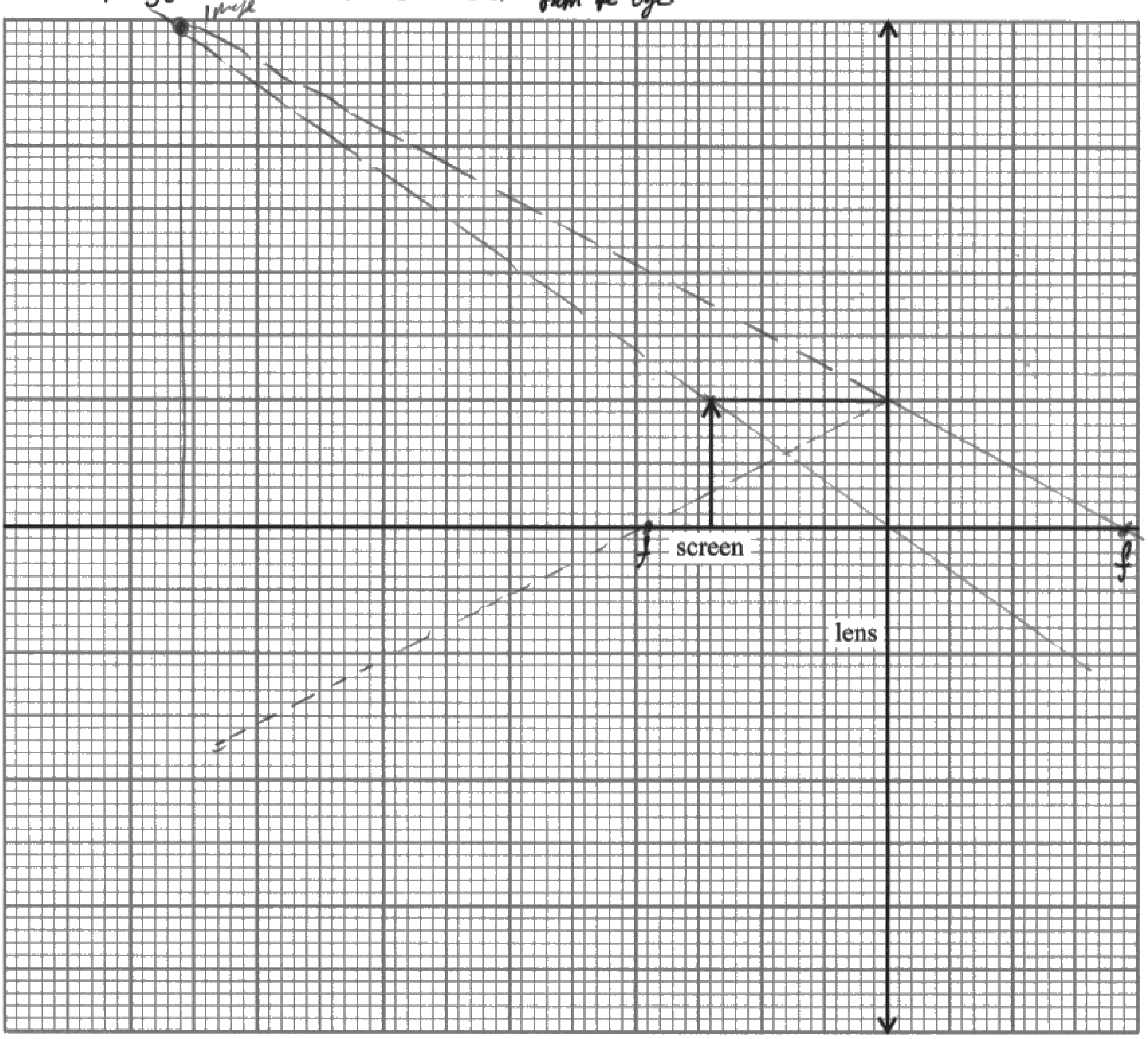
(4)

distance from screen to lens = 2.8 cm
distance from lens to eye = 2.2 cm

$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ $\frac{1}{3.5} \frac{1}{2.8} = \frac{1}{v}$ $\frac{1}{v} = \frac{.23}{266}$ $v = 10.64$ cm

$3 = \frac{v}{u}$ = $3 \times 2.8 = v$ $v = 8.4$ cm $V = 11.2$ on diagram

This is not possible with a f of 3.8. But magnification $\frac{8}{2} = 4$ so bigger than 3
16 just and be at least 16 cm from the eye



ResultsPlus
Examiner Comments

This response shows a correct ray diagram, with an image within the required range. The magnification is also within the range. The conclusion is correct, but there is not a clear comparison to the required distance to the eye, so only the first 3 marks are awarded.

(iv) For a particular user of the headset, the image of the screen must be at least 16 cm from the eye and have a magnification of at least 3.0.

Determine whether this would be possible with a lens of focal length 3.8 cm.
Your answer should include a full-scale ray diagram drawn on the grid provided.

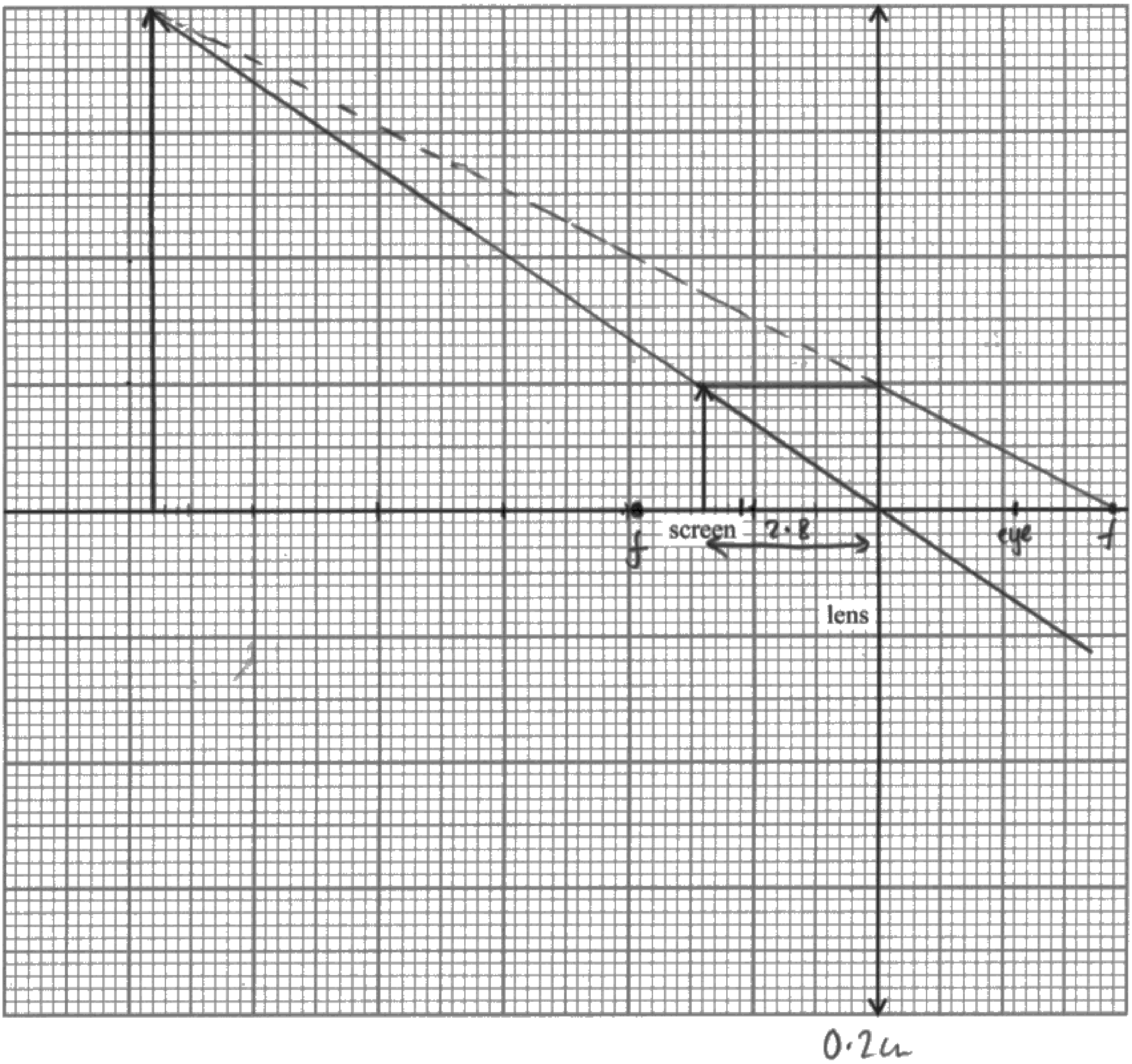
(4)

distance from screen to lens = 2.8 cm
distance from lens to eye = 2.2 cm

$\frac{1}{v} + \frac{1}{u} = \frac{1}{f}$ distance: 11.6cm + ~~5~~ 2.2cm = 13.8cm

Magnification is 4 (hence > 3)

$M = \frac{v}{u} = \frac{8}{2} = 4$ however distance is 13.8cm which is less than 16cm. Not possible



ResultsPlus
Examiner Comments

The full 4 marks are awarded for a correct diagram, correct calculations and a clear comparison.

Question 17 (b)

Nearly half the students applied Snell's law to correctly calculate the angle of refraction, but most could not go on to calculate the angle of deviation, most of them not realising the difference and apparently thinking they were the same thing as they wrote 44° on the answer line.

A failure to appreciate the idea of deviation in part (i) meant that most candidates were hindered in their approach to part (ii), so marks were infrequently awarded. Credit was most often given for the idea of all of the rays passing through the principal focus, but some students missed out by not identifying this point.

(b) Plastic Fresnel lenses are used in the VR headset because they are thinner and lighter than traditional glass lenses.

Instead of the continuous curved surface of a converging lens the Fresnel lens has circular ridges, each with an edge at a different angle to the adjacent ridge, as shown in the simplified cross-section in Figure 1. Figure 2 shows a ray of light entering a section of the lens.

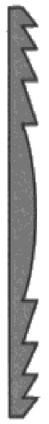


Figure 1

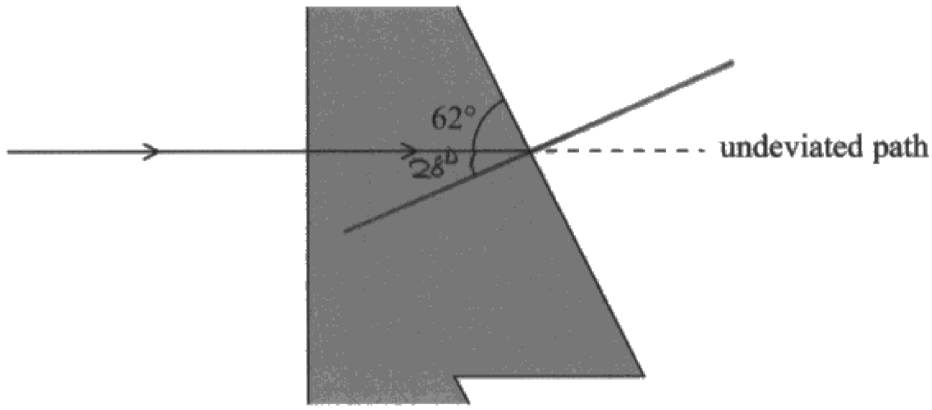


Figure 2

(i) Calculate the angle through which the ray has been deviated as it emerges from the plastic.

(4)

refractive index of plastic = 1.47

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

$1.47 \times \sin 28 = \sin\theta_2$

$0.69 = \sin\theta$

$43.6° = \theta$

Angle = 43.6°

(ii) Explain how the lens focuses a beam of light travelling parallel to the principal axis.

(3)

The lens causes refraction due to the change in optical density between the lens and the air.
The beams get refracted towards the pricipal axis as the lense is curved, each ~~fault~~ beam of light will get refracted at a different ~~[illegible]~~ angle, adjusted so that all beams are refracted to the ~~princ.~~ principal focus

ResultsPlus
Examiner Comments

(i) 2 marks awarded for correctly calculating the angle of refraction of the ray, but deviation has not been considered.

(ii) While not considering the variation in the angles of incidence and deviation, this response is awarded 1 mark for the comment about the 'beams' being refracted to the principal focus.

(b) Plastic Fresnel lenses are used in the VR headset because they are thinner and lighter than traditional glass lenses.

Instead of the continuous curved surface of a converging lens the Fresnel lens has circular ridges, each with an edge at a different angle to the adjacent ridge, as shown in the simplified cross-section in Figure 1. Figure 2 shows a ray of light entering a section of the lens.

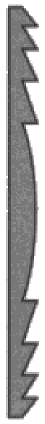


Figure 1

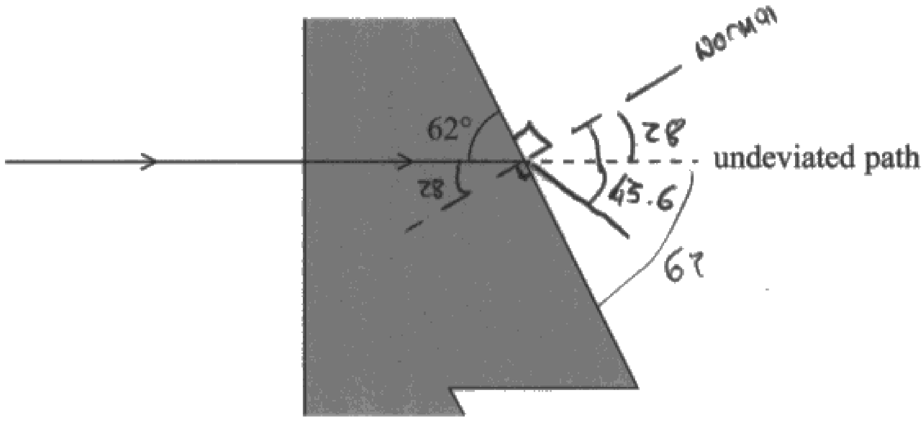


Figure 2

(i) Calculate the angle through which the ray has been deviated as it emerges from the plastic. **(4)**

refractive index of plastic = 1.47

$90-62 = 28°$

$n_1 \sin i = n_2 \sin r$

$1.47 \sin 28 = \sin r$

$\sin^{-1}(1.47 \sin 28) = r = 43.63986$

~~90~~ $90-62 = 28$

$43.6-28 = 15.6$

Angle = ~~43.6°~~ 15.6°

(ii) Explain how the lens focuses a beam of light travelling parallel to the principal axis.

(3)

Beam of light enters the lens at the flat edge. The beam travels through. Light closest to the centre is refracted less as the angle of incidence is smaller but as you travel outwards the position of the normal means that angle of incidence for the same parallel beam gets larger and larger, therefore light is refracted further and further from the parallel the further from the centre of the beam you go, creating a focus → virtual image of the object

(Total for Question 17 = 11 marks)

ResultsPlus
Examiner Comments

(i) 4 marks for calculating the angle of refraction and using it to calculate the deviation of the ray.

(ii) The first two marking points are awarded for the comments about the changing angles of incidence and their effect on the amount of refraction (2 marks).

Question 18 (a)

A majority of students completed both parts successfully. Those who failed to convert years to seconds in part (i) could still obtain 5 marks out of 6 and commonly did so.

18 Phosphogypsum is a by-product in the manufacture of fertiliser. It is slightly radioactive because of the presence of radium-226, a radioisotope with a half-life of 1600 years.

$t_{1/2} = 1600$

It must be stored securely as long as the activity of the radium-226 it contains is greater than 0.4 Bq per gram of phosphogypsum.

(a) (i) In a sample of 1.0 g of phosphogypsum, the activity of radium-226 is 1.3 Bq.

Calculate the number of nuclei of radium-226 in this sample.

(3)

$A = \lambda N$

$\lambda = \frac{\ln 2}{1600}$ $\quad \frac{1.3}{\frac{\ln 2}{1600}} = N$

$N = 3000.8$

Number of nuclei = 3001

(ii) Calculate the time in years it would take before this sample reached the permitted level of decay rate.

(3)

$A = A_0 e^{-\lambda t}$

$0.4 = 1.3 e^{-\frac{\ln 2}{1600} t}$

$\ln\left(\frac{0.4}{1.3}\right) = -\frac{\ln 2}{1600} t$

$t = -\frac{\ln\left(\frac{0.4}{1.3}\right)}{\frac{\ln 2}{1600}} = 2720.7$ years

Time = 2721 years

ResultsPlus
Examiner Comments

(i) Time has been left in years, so 2 marks are awarded for 'use of' the required formulae.

(ii) As the final answer is in years, the use of years for the calculation is acceptable (3 marks).

18 Phosphogypsum is a by-product in the manufacture of fertiliser. It is slightly radioactive because of the presence of radium-226, a radioisotope with a half-life of 1600 years.

It must be stored securely as long as the activity of the radium-226 it contains is greater than 0.4 Bq per gram of phosphogypsum.

(a) (i) In a sample of 1.0 g of phosphogypsum, the activity of radium-226 is 1.3 Bq.

Calculate the number of nuclei of radium-226 in this sample.

(3)

$\lambda = \frac{\ln 2}{t_{1/2}}$

$= \frac{\ln 2}{1600 \times 365 \times 24 \times 60 \times 60}$

$\lambda = 1.37 \times 10^{-11}$

$A = \lambda N.$

$N = A/\lambda.$

$= \frac{1.3}{1.37 \times 10^{-11}}$

$N = 9.46 \times 10^{10}$

Number of nuclei = 9.46×10^{10}

(ii) Calculate the time in years it would take before this sample reached the permitted level of decay rate.

(3)

$A = A_0 e^{-\lambda t}.$

$1.3 = 0.4 \, e^{-1.37 \times 10^{-11} t}.$

$\ln 1.3 = \ln 0.4 - 1.37 \times 10^{-11} t.$

$t = \frac{\ln 0.4 - \ln 1.3}{1.37 \times 10^{-11}}$

$t = \frac{8.6 \times 10^{10} \text{ s}}{365 \times 24 \times 60 \times 60}$

$t = 2727$ years.

Time = 2728. years

ResultsPlus
Examiner Comments

Both parts are fully correct and are awarded 3 out of 3 each.

Question 18 (b)

A large majority completed this part successfully for full marks. Some made errors in calculating the mass difference or omitted one of the steps in the calculation, obtaining 3 or 4 marks, but scores lower than this were rare.

(b) Radium-226 decays to radon-222 by alpha emission.

Determine the energy released in MeV in the decay of a single nucleus of radium-226.

(5)

mass of radium-226 nucleus = 225.97713 u

mass of radon-222 nucleus = 221.97040 u

mass of α particle = 4.00151 u

$225.97713 = 221.97040 + 4.00151 + x$

$225.97713 - 225.97191 = x$

$x = 5.2 \times 10^{-3}$ u

$1 \text{ MeV} = 1.6 \times 10^{-13}$ J

$5.2 \times 10^{-3} \times 1.66 \times 10^{-27} = 8.632 \times 10^{-30}$

$\frac{8.632 \times 10^{-30}}{1.6 \times 10^{-13}} = 5.4 \times 10^{-17}$ MeV

Energy released = 5.4×10^{-17} MeV

ResultsPlus
Examiner Comments

3 marks awarded. The student has qualified for marking points 1, 2 and 4 but has omitted the energy-mass conversion using $\Delta E = c^2 \Delta m$.

$R^{226} \rightarrow r^{222} + \alpha^4$

(b) Radium-226 decays to radon-222 by alpha emission.

Determine the energy released in MeV in the decay of a single nucleus of radium-226.

(5)

mass of radium-226 nucleus = 225.97713 u
mass of radon-222 nucleus = 221.97040 u
mass of α particle = 4.00151 u

$225.97713 - (221.97040 + 4.00151) u$

$= 5.22 \times 10^{-3} u$

$5.22 \times 10^{-3} \times 1.66 \times 10^{-27} = 8.6652 \times 10^{-30}$ Kg

$\Delta E = \Delta m c^2$

$8.6652 \times 10^{-30} \times (3 \times 10^{+8})^2 = 7.79868 \times 10^{-13}$ J

$\frac{7.79868 \times 10^{-13} \text{ J}}{1.6 \times 10^{-19}} = 4.874175 \times 10^6$ eV

4.87 MeV

Energy released = 4.87 MeV

ResultsPlus
Examiner Comments

5 marks out of 5 for a fully correct answer.

Question 19 (a)

The great majority were able to correctly calculate the luminosity of Proxima Centauri, although some did not compare it to the luminosity of the Sun. Most of these used luminosity to calculate the surface temperature, obtaining 5 marks out of 6. Many of these did not go on to score the final mark because there was not a clear and correct conclusion as required for AO3. In a number of cases this was because they did not take into account the decreasing temperature on the horizontal axis and marked the axis to the right of 3000 K. Some others had some difficulty with the logarithmic scale for luminosity.

19 In 2016 the Breakthrough Starshot initiative was announced. This project intends to send a fleet of small probes to Proxima Centauri, the nearest star to the Sun. This journey would take about twenty years.

(a) The radiation intensity at Earth from Proxima Centauri is 3.25×10^{-11} W m^{-2}.
The luminosity of the Sun is $L_{\odot}$.

(i) Show that the luminosity of Proxima Centauri is about 0.002 $L_{\odot}$.

(3)

distance to Proxima Centauri = 4.00×10^{16} m
$L_{\odot} = 3.85 \times 10^{26}$ W

$I = \frac{L}{4\pi d^2}$ $\quad 3.25 \times 10^{-11} = \frac{L}{4\pi \times (4 \times 10^{16})^2}$

$L = (3.25 \times 10^{-11}) \times 4\pi \times ((4 \times 10^{16})^2)$

$L = 6.535 \times 10^{23}$ W

~~$0.002 L_{\odot}$~~

~~$0.002 \times (3.85 \times 10^{26})$~~

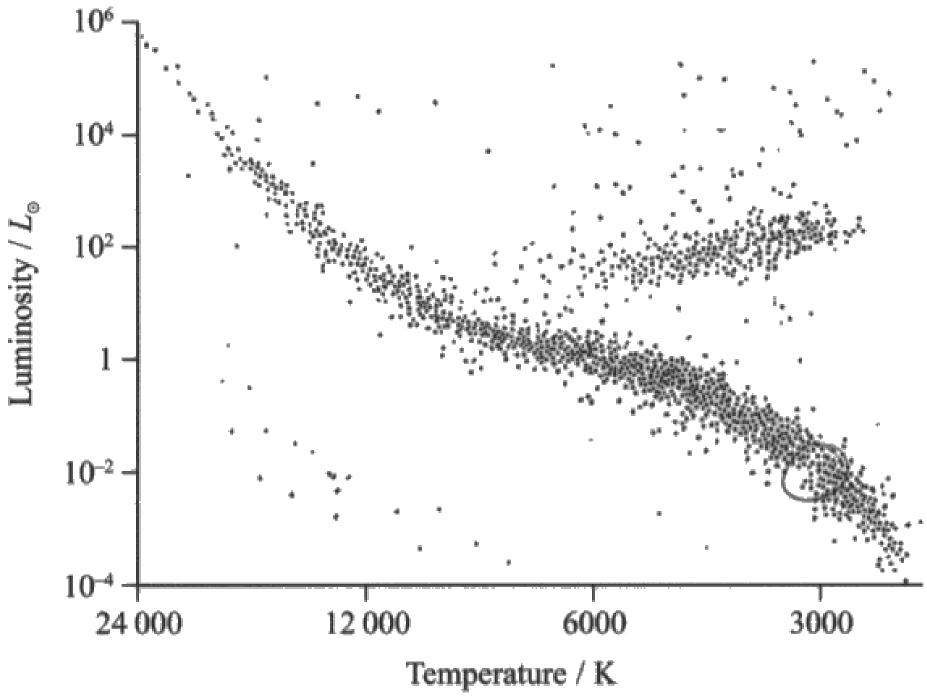
~~$= 7.7 \times 10^{23}$~~

(ii) Proxima Centauri is described on a website as a main sequence star.

Determine whether the surface temperature of Proxima Centauri is consistent with a position on the main sequence of the Hertzsprung-Russell diagram.

(3)

radius of Proxima Centauri = 9.81×10^7 m



$L = \sigma 4\pi r^2 T^4$

$6.535 \times 10^{23} = (5.67 \times 10^{-8}) \times 4\pi \times (9.81 \times 10^7)^2 \times T^4$

$T^4 = \dfrac{6.535 \times 10^{23}}{(5.67 \times 10^{-8}) \times 4\pi \times (9.81 \times 10^7)^2}$

$T^4 = 9.53 \times 10^{13}$ $T = \sqrt[4]{9.53 \times 10^{13}}$ $T = 3124.45$ K

The surface temperature of Proxima Centauri is consistent with a position on the main sequence

ResultsPlus
Examiner Comments

(i) 2 marks - The luminosity has been calculated correctly, but the fraction of the Sun's luminosity has not. The student has calculated 0.002 of the luminosity of the Sun, but then crossed it out.

(ii) 2 marks - The calculation of surface temperature is correct, but the comparison point of the graph is indicated by a circle that is too large and centred on the wrong point.

19 In 2016 the Breakthrough Starshot initiative was announced. This project intends to send a fleet of small probes to Proxima Centauri, the nearest star to the Sun. This journey would take about twenty years.

(a) The radiation intensity at Earth from Proxima Centauri is 3.25×10^{-11} W m^{-2}.
The luminosity of the Sun is $L_{\odot}$.

(i) Show that the luminosity of Proxima Centauri is about $0.002\ L_{\odot}$.

(3)

distance to Proxima Centauri = 4.00×10^{16} m
$L_{\odot} = 3.85 \times 10^{26}$ W

~~$L = \sigma 4\pi r^2 T^4$~~

~~$3.25 \times 10^{-11} = 5.67 \times 10^{-8} \times 4 \times \pi \times (4.00 \times 10^{16})^2 \times T^4$~~

$I = \frac{L}{4\pi d^2}$

$3.25 \times 10^{-11} = \frac{L}{4 \times \pi \times (4 \times 10^{16})^2}$

$L = \frac{6.5345 \times 10^{23}}{3.85 \times 10^{26}}$

$= 1.69 \times 10^{-3}$

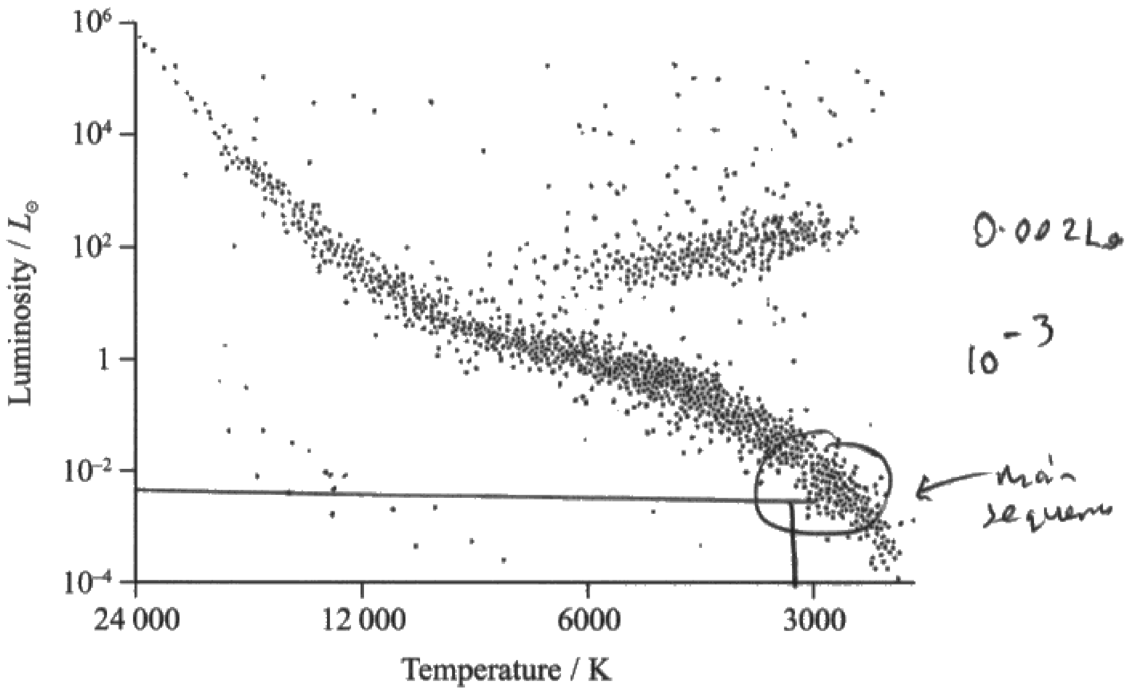
$= 0.00169\ L_{\odot}$

(ii) Proxima Centauri is described on a website as a main sequence star.

Determine whether the surface temperature of Proxima Centauri is consistent with a position on the main sequence of the Hertzsprung-Russell diagram.

(3)

radius of Proxima Centauri = 9.81×10^7 m



$L = \sigma \times 4 \times \pi r^2 \times T^4$

$\sqrt[4]{\frac{L}{\sigma \times 4 \times \pi \times r^2}} = T$

$T = \sqrt[4]{\frac{~~6.5345\times10^{23}~~ \; 6.5345\times10^{23}}{5.67\times10^{-8} \times 4 \times \pi \times (9.81\times10^7)^2}}$

$= 3124.42$ K

Yes, it is consistent, because proxima centauri is about 3124.42 K, and a luminosity of $0.002L_\odot$, which is main sequence area of the diagram

ResultsPlus
Examiner Comments

(i) 3 marks for a correct calculation of luminosity used to determine a correct ratio to the required extra significant figure.

(ii) 3 marks for a correct calculation and an exemplary conclusion.

Question 19 (b)

This is not a new topic on the specification, although it is likely to have been studied in year 12 as it is in the AS section, so the overall poor response was somewhat surprising. It might have been because the question was about an absorption spectrum rather than an emission spectrum, which occurs more frequently in past papers, although the specification just refers to line spectra. A number of students did not appear to recognise line spectra as the subject of the question and instead focused on the Doppler Effect.

The required points in the mark scheme are the standard points used for many years, but insufficient detail was given by the majority of students so that many scored no marks at all. Discrete energy levels were often not mentioned and neither were photons, which were required for 3 of the marks.

(b) The composition of a star can be determined by analysis of its absorption spectrum.

Explain why there are certain specific frequencies missing from the spectrum.

(5)

A photon is absorbed when the difference in the energy level is equal to the energy of the photon. A photon is absorbed by an electron, the electron moves to a higher energy level. There are certain frequencies missing as each photon absorbed at only certain frequencies when there is a certain difference.

ResultsPlus
Examiner Comments

The first sentence of this response corresponds to marking point 3 and the second to marking point 2 for a total of 2 marks.

ResultsPlus
Examiner Tip

Learn standard descriptions of physical processes, such as the production of atomic line spectra, and be able apply them with sufficient detail to specific situations, such as absorption spectra in this case.

(b) The composition of a star can be determined by analysis of its absorption spectrum.

Explain why there are certain specific frequencies missing from the spectrum.

(5)

Electrons ~~at~~ orbit ~~the~~ atomic nuclei at discrete energy levels. If an electron absorbs a photon with energy that is equal to the energy difference between two energy levels, the electron is excited to a higher energy level. When the electron moves back down to a more stable orbit, the energy is emitted in all directions, so the observed intensity is negligible. Only photons with the exact energy needed to excite an electron are absorbed and since E=hf, only certain frequencies appear to be 'missing' from the spectrum. Since different elements have different differences between energy levels, different photon frequencies are absorbed by different elements, meaning analysis of a ~~star~~ star's absorbtion spectrum means its composition can be determined.

ResultsPlus
Examiner Comments

This is an excellent response and gains 5 marks out of 5.

Question 19 (c)

In contrast to part (b), this part was answered well, with over half of the students being awarded at least 2 marks. The most common missing element in the answer was a reference to background stars. Many students gained at least 2 marks for their use of a diagram, which is relevant for this topic.

A few students described incorrect methods for nearby stars, such as the use of standard candles.

(c) Describe how the distance to nearby stars like Proxima Centauri is determined.

(3)

The distance can be determined using standard candles which are stars of known luminosity which can be used for stars which are too far away from us for parallax to be used.

ResultsPlus
Examiner Comments

Despite the question stating that Proxima Centauri is the nearest star to the Sun, this answer explicitly refers to stars that are too far away for parallax to be used and suggests standard candles (0 marks).

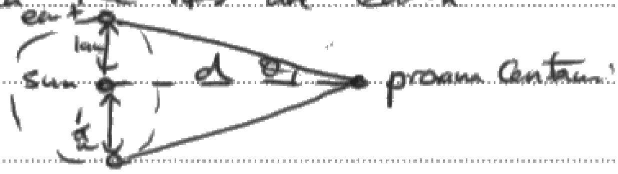
ResultsPlus
Examiner Tip

Be sure to learn the relevant parts of the 'Cosmic distance ladder', the distances at which they apply and the reasons.

(c) Describe how the distance to nearby stars like Proxima Centauri is determined.

(3)

• Take the parallax angle between the star and earth over a six month period



• As we know the distance to the sun and have called it 1 au then we can use $\tan\theta = \frac{1}{d}$ ∴ $d = \frac{1}{\tan\theta}$.

• This only works for nearby stars as the percentage uncertainty when reading the angle is low as the angle is relatively large.

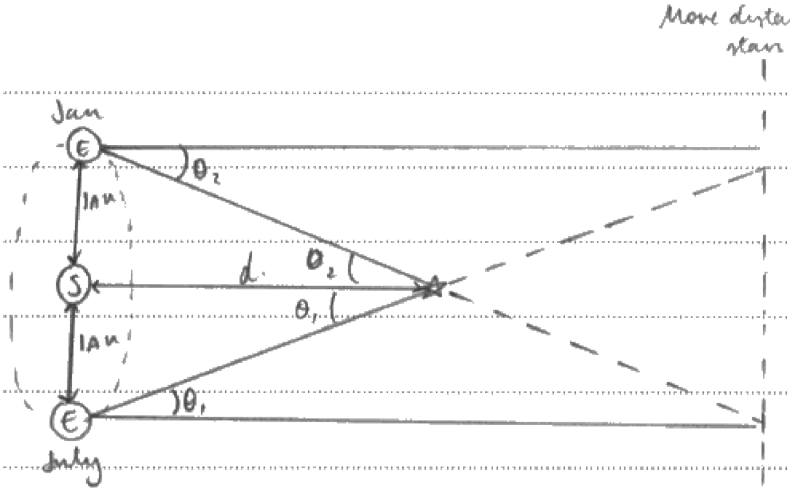
ResultsPlus

Examiner Comments

2 marks awarded in total for marking points 1 and 3, but there is no reference to fixed distant stars.

(c) Describe how the distance to nearby stars like Proxima Centauri is determined.

(3)



$\tan\theta = \frac{AU}{d}$

The change in angle between the nearby star and more distant stars is measured across 6 months. ~~6 months apart~~ Trigonometry is then used to calculate the distance from the sun to the nearby star, using the known distance between the earth and the sun.

ResultsPlus
Examiner Comments

3 marks out of 3 were awarded for a very clear answer.

Paper Summary

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

- There are no extra marks for completing multiple choice questions 'in your head', so students should be ready to write them out on the paper.

- Be sure you know the command words and understand the level of required response for each of them, e.g. explain would mean a student must say why something happens and not just describe what happens. There will always be at least two linked marking points for a question asking you to 'explain'.

- Where you are asked to make a judgement or come to a conclusion by command words such as 'determine whether', 'explain whether' or 'deduce whether', you must make a clear statement, including any values being compared.

- Check that quantitative answers represent sensible values and to go back over calculations when they do not.

- Learn standard descriptions of physical processes, such as the production of atomic line spectra, and be able apply them with sufficient detail to specific situations, identifying the parts of the general explanation required to answer the particular question.

- In questions with mixed quantities, be sure to convert all values to standard SI base units or derived units, e.g. convert years or hours to seconds, °C to K, nm, mm and km to m.

- 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, e.g. x^2, don't suddenly miss off the index when substituting or forget it in the calculation, such as failing to calculate a square root.

- When using graphs, read the scale values on either side of the point of interest to ensure you are using the scale correctly.

- Remember that phase difference is expressed as an angle and path difference is expressed in terms of distance or wavelengths.

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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