Examiners' Report
June 2025

GCE Physics 9PH0 02

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Introduction

The assessment structure of Advanced Paper 2 mirrors that of Paper 1. It includes ten multiple-choice questions, followed by a series of short-answer questions and longer, structured questions based on contexts with varying degrees of familiarity.

This paper provided candidates across the full ability range with opportunities to demonstrate their knowledge and understanding of Physics by applying it to diverse scenarios.

Candidates performing at the lower end of the spectrum were generally able to complete calculations involving straightforward substitution and limited rearrangement, including structured sequences of calculations. However, they often struggled with more complex, multi-step problems – particularly those involving ratios or the interpretation of logarithmic scales. In explanation-based questions, they often recalled some key points related to familiar topics, such as resonance in simple harmonic motion, but frequently omitted important details and sometimes failed to present their ideas in a logical order.

In some cases, candidates used additional space to expand or revise their answers. When doing so, they should clearly indicate where this extra information can be found.

Overall, a steady improvement was evident across the range of abilities. At the higher end, candidates completed all calculations accurately and produced well-structured explanations that included most or all relevant points.

Question 11

Candidates generally scored quite well on this question, with the majority scoring at least 2 marks. There were some commonly seen errors, which did lead to marks not being awarded. The use of the incorrect denominator in the doppler equation meant that marking point 1 could not be awarded. Marking point 2 was sometimes not awarded due to unit omission. Marking point 3 was dependent on seeing the correct change in wavelength calculated.

11 A spectral line with wavelength 655.88 nm is detected on Earth from the Triangulum Galaxy. The wavelength of this spectral line measured using a laboratory source is 656.28 nm.

Calculate the velocity of the Triangulum Galaxy relative to the Earth.

$$\frac{\Delta\lambda}{\lambda} = \frac{|655.88 - 656.28|}{656.28} = 6.09 \times 10^{-4}$$

$$6.09 \times 10^{-4} = \frac{v}{c}$$

$$v = 6.09 \times 10^{-4} \times 3 \times 10^{8}$$

$$= 183000 \text{ ms}^{-1}$$

$655.88 < 656.28$

$\therefore$ towards earth

Magnitude of velocity = 183000 ms^{-1}

Direction = towards Earth

ResultsPlus
Examiner Comments

Here we see the correct change in wavelength calculated. The denominator is correct, the speed they have calculated is correct and has a correct unit. The direction is correct. This scores all 3 marks.

11 A spectral line with wavelength 655.88 nm is detected on Earth from the Triangulum Galaxy. The wavelength of this spectral line measured using a laboratory source is 656.28 nm.

Calculate the velocity of the Triangulum Galaxy relative to the Earth.

$\Delta\lambda = 656.28 - 655.88 = 0.4\,nm$

$z = \frac{\Delta\lambda}{\lambda} = \frac{0.4}{656.28} = 6.09496 \times 10^{-4} = \frac{v}{c}$

$v = 6.09496 \times 10^{-4} \times 3 \times 10^{8}$

$V = 1.83 \times 10^{5}\,ms^{-1}$

Magnitude of velocity = $1.83 \times 10^{5}\,ms^{-1}$

Direction = Towards earth

ResultsPlus
Examiner Comments

This scored 2 marks. The third mark could not be awarded as the candidate has incorrectly calculated the change in wavelength.

11 A spectral line with wavelength 655.88 nm is detected on Earth from the Triangulum Galaxy. The wavelength of this spectral line measured using a laboratory source is 656.28 nm.

Calculate the velocity of the Triangulum Galaxy relative to the Earth.

$$\frac{656.28 - 655.88}{655.88} = \frac{10}{16397}$$

$$v \approx \frac{10}{16397} \times 3\times10^8 = 1.83\times10^5\ ms^{-1}$$

Magnitude of velocity = $1.83\times10^5\ ms^{-1}$

Direction = Away from earth.

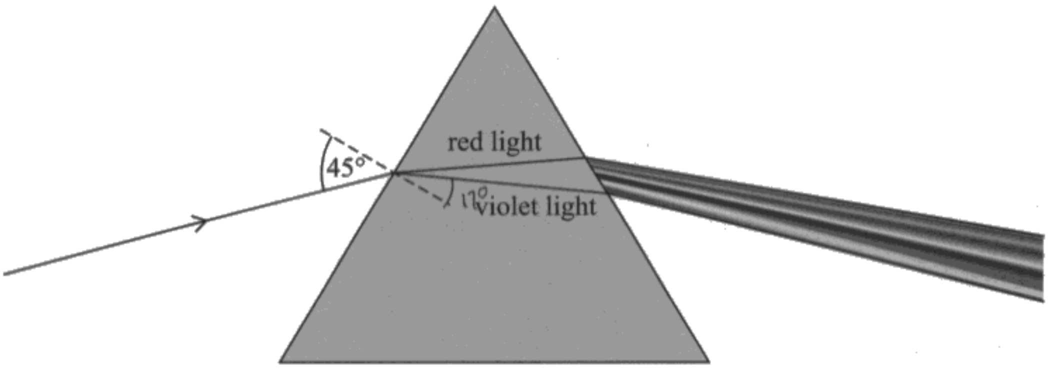
ResultsPlus
Examiner Comments

This response scored marking point 2 only for the correct magnitude of the velocity with a correct unit. The denominator is wrong, and so is the direction, so no further marks can be awarded.

Question 12

Whilst some candidates found this question challenging, a significant number of responses scored all four marks. This was for correctly determining the ratio of the speeds and making a comparison between the calculated ratio and the given ratio, or for calculating the angle and comparing it to the angle from the diagram. In order to score the fourth mark a mathematical comparison and a conclusion was necessary.

12 The image from the cover of a music album is represented below.



White light enters the prism at an angle of incidence of 45°. The light disperses and splits into a spectrum of colours as it enters the prism.

In this image the angle of refraction for violet light at the first boundary is 22°. The angle between the red light and the violet light is 11°.

Evaluate whether the angle between the red light and the violet light is accurate.

$$\frac{\text{speed of violet light in prism}}{\text{speed of red light in prism}} = 0.99$$

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

$1 \times \sin 45 = n_2 \sin 22$

$n_2 = 1.89$

$V = \frac{c}{n}$

$V_v = \frac{3 \times 10^8}{1.89}$

$= 1.59 \times 10^8 \text{ ms}^{-1}$

$V_r = \frac{1.59 \times 10^8}{0.99}$

$= 1.61 \times 10^8 \text{ ms}^{-1}$

$n = \frac{c}{V_r} = \frac{3 \times 10^8}{1.61 \times 10^8} = 1.87$

$1 \times \sin 45 = 1.87 \sin\theta$

$\theta = 22.2°$

$\angle$between R and V $= 22.2 - 22 = 0.2°$

$0.2 \neq 11°$ ∴ angle isnt acuate.

(Total for Question 12 = 4 marks)

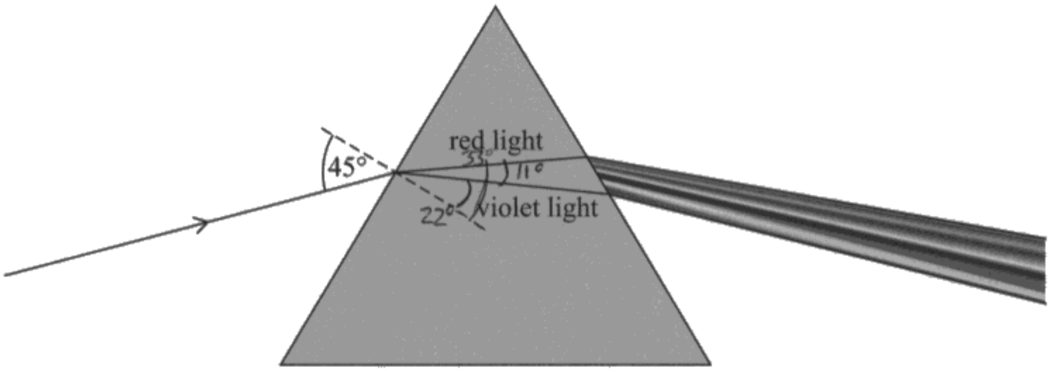
ResultsPlus
Examiner Comments

Here we see the use of Snell's law to calculate the refractive index of violet light. The candidate then uses this value with n=c/v to determine the speed of the violet light. They then use the ratio of the speeds to calculate the speed of the red light. The refractive index of red light is then determined and the candidate goes on to use this correctly with Snell's law to determine the correct angle. They then make a mathematical comparison and state that the angle isn't accurate. This scored all four marks.

ResultsPlus
Examiner Tip

When the command word is evaluate always include a mathematical comparison between the calculated value and the reference value from the question. This needs to be supported by a conclusion.

12 The image from the cover of a music album is represented below.



White light enters the prism at an angle of incidence of 45°. The light disperses and splits into a spectrum of colours as it enters the prism.

In this image the angle of refraction for violet light at the first boundary is 22°. The angle between the red light and the violet light is 11°.

Evaluate whether the angle between the red light and the violet light is accurate.

$$\frac{\text{speed of violet light in prism}}{\text{speed of red light in prism}} = 0.99$$

$n_1 \sin\theta_1 = n_2 \sin\theta_2$, $n = \frac{c}{v}$

$\hookrightarrow n_2 = \frac{n_1 \sin\theta_1}{\sin\theta_2} = \frac{1 \times \sin 45}{\sin 22} = 1.89$

$V = \frac{c}{n} = \frac{3\times10^8}{1.89} = 1.589\times10^8\ ms^{-1}$ (Violet)

$\hookrightarrow n_2 = \frac{\sin 45}{\sin 33} = 1.298$

$V = \frac{3\times10^8}{1.298} = 2.31\times10^8\ ms^{-1}$ (Red)

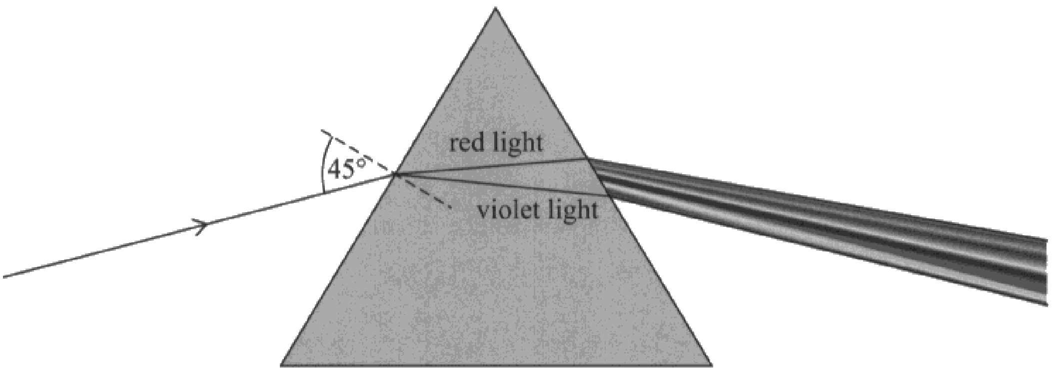
$\frac{1.589\times10^8}{2.31\times10^8} = 0.69$, So the angle is not accurate

(Total for Question 12 = 4 marks)

ResultsPlus
Examiner Comments

This response scored the first 3 marks, as the ratio of the speeds have been correctly calculated. However, the fourth mark was not awarded as no mathematical comparison is provided. To score the final mark 0.69 is not equal to 0.99 was required.

12 The image from the cover of a music album is represented below.



White light enters the prism at an angle of incidence of 45°. The light disperses and splits into a spectrum of colours as it enters the prism.

In this image the angle of refraction for violet light at the first boundary is 22°. The angle between the red light and the violet light is 11°.

Evaluate whether the angle between the red light and the violet light is accurate.

$$\frac{\text{speed of violet light in prism}}{\text{speed of red light in prism}} = 0.99$$

$\sin 45 = n_2 \sin 22 \Rightarrow n_2 = \frac{\sin 45}{\sin 22} = 1.8876$

ResultsPlus
Examiner Comments

Here we see the use of Snell's law to correctly determine the refractive index for the violet light. But no further working has been provided after this. Therefore, this response scores 1 mark.

Question 13

This question was generally very well answered with the vast majority of responses scoring 4 or 5 marks. The second, third and fourth marking points were frequently awarded for correct calculations. The first mark was for stating the work function is the minimum photon energy for an electron to be emitted. This could also be scored for stating a minimum frequency must be exceeded, or that electrons are only emitted when the wavelength is below a maximum value. When responses did not score full marks, this point was often omitted.

The final mark was for a comparison between the calculated value and the threshold case. This needed to be done for both UV and visible light. When this mark was not awarded it was usually due to no comparison being made or only comparing UV or visible to the threshold case.

13 A teacher demonstrated the photoelectric effect by illuminating a zinc plate with electromagnetic radiation.

When ultraviolet radiation of wavelength 320 nm was incident upon the zinc plate, electrons were emitted from the zinc surface.

When visible light of wavelength 420 nm was incident upon the zinc plate, no effect was observed.

Explain these observations. Your answer should include calculations.

work function of zinc = 3.74 eV

$E = hf$

$E_1 = 6.63 \times 10^{-34} \times 9.375 \times 10^{14} = 6.22 \times 10^{-19}$ J

$(\div 1.6 \times 10^{-19})$

$= 3.88$ eV

(3 s.f)

$v = f\lambda$

$f_1 = \frac{v}{\lambda} = \frac{3 \times 10^8}{320 \times 10^{-9}} = 9.375 \times 10^{14}$ Hz

$E_2 = 6.63 \times 10^{-34} \times 7.14 \times 10^{14} = 4.74 \times 10^{-19}$ J

$(\div 1.6 \times 10^{-19})$

$= 2.96$ eV

(3 s.f)

$f_2 = \frac{3 \times 10^8}{420 \times 10^{-9}} = 7.14 \times 10^{14}$ Hz

The energy of a photon of uv light is 3.88eV, which is greater than the work function of zinc, however the energy of a photon of the visible light is 2.96eV, which is less than the work function. ∴ ~~only~~ electrons are only emitted with uv light as the energy of the incoming photon must be greater than or equal to the work function as the work function of a metal is the minimum energy required to release an electron from photoelectric effect, ∴ ~~the~~ electrons can be emitted with uv but not visible light.

(Total for Question 13 = 5 marks)

ResultsPlus
Examiner Comments

This response scores all five marks. Correct calculations to determine the photon energy in electronvolts for UV and visible light score the marking points 2, 3 and 4. The candidate then goes on to compare these energies to the work function for UV and visible light and finally includes the definition of the work function.

13 A teacher demonstrated the photoelectric effect by illuminating a zinc plate with electromagnetic radiation.

When ultraviolet radiation of wavelength 320 nm was incident upon the zinc plate, electrons were emitted from the zinc surface.

When visible light of wavelength 420 nm was incident upon the zinc plate, no effect was observed.

Explain these observations. Your answer should include calculations.

work function of zinc = 3.74 eV

Ultraviolet:

$v = \lambda f$

$3\times10^8 = 320\times10^{-9} f$

$f_{UV} = 9.375\times10^{14}$

$E_{UV} = h \times 9.375\times10^{14}$

$= 6.215625\times10^{-19}$ J

$= 3.88$ eV

Visible:

$f_V = \frac{3\times10^8}{420\times10^{-9}} = 7.14\times10^{14}$

$E_V = h\times7.14\times10^{14}$

$= 4.736\times10^{-19}$ J

$= 2.96$ eV

3.88 > 3.74 while 2.96 is not greater than 3.74.

Electrons emitted for UV because exceeds work function and not for visible light as it doesn't exceed it

(Total for Question 13 = 5 marks)

ResultsPlus
Examiner Comments

This scores 4 marks. The calculations and comparisons are correct. However, the candidate has not stated what the work function is. We need to see the idea that it is the minimum photon energy for photoelectric emission to occur. The first marking point was therefore not awarded.

13 A teacher demonstrated the photoelectric effect by illuminating a zinc plate with electromagnetic radiation.

When ultraviolet radiation of wavelength 320 nm was incident upon the zinc plate, electrons were emitted from the zinc surface.

When visible light of wavelength 420 nm was incident upon the zinc plate, no effect was observed.

Explain these observations. Your answer should include calculations.

work function of zinc = 3.74 eV → J $\quad 1.60 \times 10^{-19}$

$\phi = 5.984 \times 10^{-19}$ J

$hf = \phi + \frac{1}{2}mv^2_{max}$

ResultsPlus
Examiner Comments

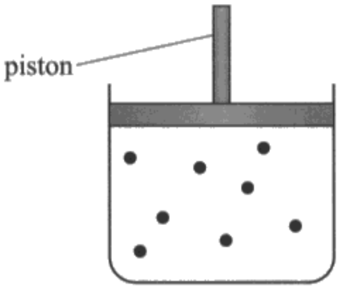
Here we can see the candidate has correctly converted the work function from eV to J. They have not shown all of their working, but this was sufficient to award marking point 4.

Question 14

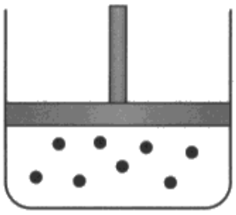
This question involved extended writing to discuss how changing the volume of gas will affect the pressure. Candidates found the question accessible with the vast majority being able to score at least 2 marks. There were some excellent responses which scored all 6 marks; however, these were not seen frequently.

It is worth noting that in order for IC1, IC2 and IC5 to be awarded, reference needed to be made to collisions between the molecules and the walls of the container or piston. In the case of IC2, this could only be scored if the response referred to an increase in the rate or frequency of the collisions. IC3 required reference to the velocity of the molecules being constant or that the change in momentum per collision is constant. IC4 was awarded for rate of change of momentum increases. IC5 was for increase in force of collisions against the walls or piston, this was often awarded. IC6 was for P=F/A and pressure increases was also commonly awarded.

***14** Air molecules are trapped in a container by a piston, as shown.



The position of the piston is adjusted so that the volume available to the air molecules is reduced. The temperature of the air stays constant.



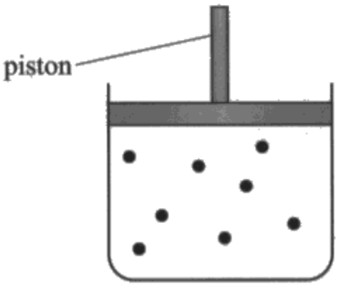
Explain how the pressure exerted by the air changes. You should refer to the motion of the air molecules.

As the volume of the chamber decreases, and the temperature remains constant: the average distance molecules need to travel between collisions with the walls of the chamber decreases, and the average KE (so average velocity in 3D) remains constant. This means the time taken between collisions on average decreases, so the overall rate of collisions increases. Rate of change in momentum p of ~~each particle~~ each particle also increases (which is proportional to the force on the particle by N2: $\Sigma F = \frac{\Delta p}{\Delta t}$). From N3, the force on the walls also increases: by $P = \frac{F}{A}$, pressure also increases. Therefore as volume has decreased, this means the pressure must increase (pressure from the air acting on the walls). As the collisions between the particles and walls are elastic, and there are assumed to be no collisions between the molecules within the chamber.

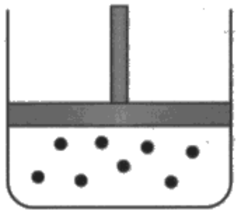
ResultsPlus
Examiner Comments

This response scores IC1 in line 2 and IC3 in line 3. IC2 is awarded in line 4 as the candidate has been clear that the collisions are between the molecules and the walls of the container earlier in the response. IC4 is scored in line 4 and 5. IC5 and IC6 are awarded in lines 6 and 7 respectively. There is a logical sequence to the response, so this scores all 6 marks.

*14 Air molecules are trapped in a container by a piston, as shown.



The position of the piston is adjusted so that the volume available to the air molecules is reduced. The temperature of the air stays constant.



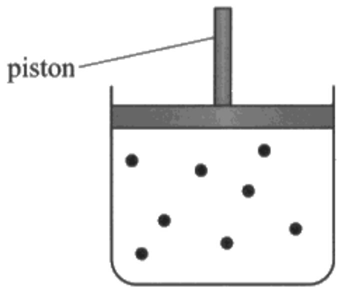
Explain how the pressure exerted by the air changes. You should refer to the motion of the air molecules.

Assuming the air is behaving as an ideal gas, boyles law states for a constant temperature pressure is inversely proportional to volume. $p = \frac{1}{V}$. As the piston pushes down the volume of the container decreases. As the temperature is constant the kinetic energy of the particles is also constant. Therefore as the volume decreases particles collide with the container more frequently. An increase in collisions leads to an increase in force exerted on the container. As pressure $= \frac{\text{Force}}{\text{Area}}$. The force has increased and the surface area decreased so pressure increases.

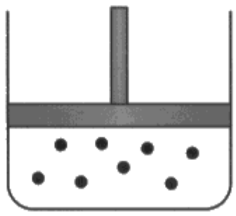
ResultsPlus
Examiner Comments

Here IC2 is awarded in line 7 for the idea that the frequency of collisions has increased. IC5 is awarded in line 9 and IC6 is awarded in line 10 and 11. This response scores 3 marks.

***14** Air molecules are trapped in a container by a piston, as shown.



The position of the piston is adjusted so that the volume available to the air molecules is reduced. The temperature of the air stays constant.



Explain how the pressure exerted by the air changes. You should refer to the motion of the air molecules.

As temprature remains constant, Pressure is inversly proportional to the volume. This is given by Boyles law. As volume decreases in the container, the pressure will increase. This means the air molecules will collide more frequently. More collisions ~~[illegible]~~ means that the kinetic energy of the molecules will increase.

ResultsPlus
Examiner Comments

This response did not score IC6, as the candidate said that pressure increases but did not define what pressure was. IC2 could not be awarded, even though the idea of the frequency of collisions increasing is there, they have not said that the molecules collide with the walls of the container or piston. This scores 0 marks.

Question 15(a)

In this question candidates needed to calculate the wavelength of a gamma ray, having been given its energy in eV. This was generally very well answered, with the vast majority of responses scoring full marks. Occasionally a mark was lost for the omission of the unit in the final answer.

15 A pulsar is a rotating neutron star. The pulsar emits electromagnetic radiation as it rotates.

Scientists have recently detected the highest ever energy gamma ray photons received from a pulsar.

(a) The energy of one of these gamma ray photons was determined to be 2.0×10^{13} eV.

Calculate the wavelength of these gamma rays.

(4)

$E = hf = \frac{hc}{\lambda}$ $\quad E_J = 2 \times 10^{13} \times 1.6 \times 10^{-19}$

$= 3.2 \times 10^{-6}$ J

$\Rightarrow \lambda = \frac{hc}{E}$

$\cancel{3.2 \times 10^{-6}}$ $\lambda \cancel{3.2 \times 10^{-6}} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{3.2 \times 10^{-6}}$

$\lambda = 6.22 \times 10^{-20}$ m

Wavelength = 6.22×10^{-20} m

ResultsPlus
Examiner Comments

This response scores all 4 marks. The candidate has correctly converted eV to J, correctly used E=hf and c=fλ to arrive at the correct answer and included the correct unit.

ResultsPlus
Examiner Tip

Unless it is a show that question, where units are given in the question stem, the final answer mark always depends on including a correct unit.

15 A pulsar is a rotating neutron star. The pulsar emits electromagnetic radiation as it rotates.

Scientists have recently detected the highest ever energy gamma ray photons received from a pulsar.

(a) The energy of one of these gamma ray photons was determined to be 2.0×10^{13} eV.

Calculate the wavelength of these gamma rays.

(4)

$E = 2\times10^{13}$ eV $= 2\times10^{13} \times 1.6\times10^{-19} = 3.2 \times 10^{-6}$ J

$E = hf \qquad f = \frac{v}{\lambda} = \frac{c}{\lambda}$

$E = h\left(\frac{c}{\lambda}\right)$

$\lambda = \frac{c}{(E/h)} = \frac{3\times10^{8}}{\left(\frac{3.2\times10^{-6}}{6.63\times10^{-34}}\right)} = 6.22\times10^{-20}$

Wavelength = 6.22×10^{-20}

ResultsPlus
Examiner Comments

This scored 3 marks for the calculations. However, due to the omission of the unit, the final mark could not be awarded.

ResultsPlus
Examiner Tip

Always include units.

15 A pulsar is a rotating neutron star. The pulsar emits electromagnetic radiation as it rotates.

Scientists have recently detected the highest ever energy gamma ray photons received from a pulsar.

(a) The energy of one of these gamma ray photons was determined to be 2.0×10^{13} eV.

Calculate the wavelength of these gamma rays.

(4)

$2 \times 10^{13} \times 1.6 \times 10^{-19} = 3.2 \times 10^{-6}$ J $\quad 3.2 \times 10^{-6} = hf \quad f = \frac{3.2 \times 10^{-6}}{h} = 4.83 \times 10^{27}$

Wavelength = ...

ResultsPlus Examiner Comments

Here we see the full calculation to convert eV to J, scoring the first mark. The candidate has not fully substituted all of the values into E=hf, but the frequency they have calculated is correct and it is not a show that question, so in this case the second mark is also awarded. No further response has been provided, so this scores 2 marks.

ResultsPlus Examiner Tip

Always substitute all values into equations.

Question 15(b)

This question proved to be more challenging, with around half of the responses scoring the mark. Here we were looking for a comparison between the speed of the pulsar and the speed of light, or a calculation of the redshift with a valid conclusion.

(b) The pulsar is estimated to be travelling away from the Earth with a velocity of $750\,\mathrm{m\,s^{-1}}$.

State why this motion away from the Earth does not significantly affect the wavelength of radiation received at the Earth.

(1)

$\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$ Speed of light is 3×10^8, So much greater than 750, making $\frac{v}{c}$ near 0. Therefor $\Delta\lambda$ must be near 0, ∴ does not affect wavelength significantly

ResultsPlus
Examiner Comments

Here the mark was awarded, as the idea that the speed of light is much greater than the speed of the pulsar is a creditworthy response.

(b) The pulsar is estimated to be travelling away from the Earth with a velocity of $750\,m\,s^{-1}$.

State why this motion away from the Earth does not significantly affect the wavelength of radiation received at the Earth.

(1)

Because the ~~wa~~ radiation received at the Earth was emitted when the pulsar was closer to the ~~earth~~ Earth.

ResultsPlus
Examiner Comments

A fairly common incorrect response. It is possible the candidate is confusing the doppler effect with Hubble's law, but reference to the distance of the pulsar does not score the mark.

(b) The pulsar is estimated to be travelling away from the Earth with a velocity of $750\,m\,s^{-1}$.

State why this motion away from the Earth does not significantly affect the wavelength of radiation received at the Earth.

(1)

Wavelength is ~~so~~ small that redshift won't have much effect

ResultsPlus
Examiner Comments

This response was not credited with the mark. In this case, this is because the candidate is talking about redshift and not making a comparison of the speed of the pulsar to the speed of light. To score the mark, a calculation would have been needed.

Question 16(a)

This question proved to be quite challenging, with only around half of the candidates scoring the mark. When a virtual image is formed by a converging lens, it is because the distance between the object and the lens is less than the distance to the focal point. As the question talks about correcting vision, near objects would be a distance away which is less than the focal length.

16 The closest distance from the eye where light from an object can be brought to a focus is known as the near point distance. The near point distance for a human eye is taken to be 25 cm.

A long-sighted eye has a near point distance greater than 25 cm. This may cause problems with focusing on near objects.

A converging lens can be used to correct this problem. The converging lens forms an image of a near object at the actual near point distance of the long-sighted eye.

(a) State the type of image formed by the converging lens when used to correct a long-sighted eye.

(1)

VIRTUAL

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Examiner Comments

The mark was awarded for an answer exactly as in the mark scheme.

16 The closest distance from the eye where light from an object can be brought to a focus is known as the near point distance. The near point distance for a human eye is taken to be 25 cm.

A long-sighted eye has a near point distance greater than 25 cm. This may cause problems with focusing on near objects.

A converging lens can be used to correct this problem. The converging lens forms an image of a near object at the actual near point distance of the long-sighted eye.

(a) State the type of image formed by the converging lens when used to correct a long-sighted eye.

(1)

real and inverted

ResultsPlus
Examiner Comments

The answer is incorrect, so no mark is awarded.

Question 16(b)

This question was to work out the power of the lens to correct a long-sighted eye. In general it was fairly well answered, with the majority of candidates scoring at least 2 marks. Common mistakes included attempting to add powers, or incorrect use of sign convention.

(b) The near point distance for a long-sighted eye is 65 cm.

Calculate the power, in dioptres, of the converging lens required.

(3)

$$\frac{1}{0.25} - \frac{1}{0.65} = \frac{1}{f} = P = \frac{32}{13} \text{ D}$$

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

$$= 2.46 \text{ D}$$

$$= 2.5 \text{ D} \ (2.4)$$

Power of converging lens = 2.5 D D

ResultsPlus
Examiner Comments

This response scored the first marking point for correct use of the thin lens equation. The image was virtual, so 1/0.65 needed to be subtracted. They have correctly used P=1/f, and the final answer is correct. There is no evidence of adding powers, so this response scores all 3 marks.

(b) The near point distance for a long-sighted eye is 65 cm.

Calculate the power, in dioptres, of the converging lens required.

(3)

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

$\frac{1}{0.25} + \frac{1}{0.65} = \frac{1}{f}$ $\quad = \frac{1}{0.18}$

$f = 0.18\,m$ $\quad = 5.56\,D$

Power of converging lens = 5. 56 D

ResultsPlus
Examiner Comments

The first 2 marks can be awarded here, as the mark scheme states ignore sign convention for MP1 and MP2. So a mark is awarded for use of the thin lens equation and also for use of P=1/f. The third mark cannot be awarded as the final answer is incorrect.

(b) The near point distance for a long-sighted eye is 65 cm. 0.65 m

Calculate the power, in dioptres, of the converging lens required.

(3)

$P = \frac{1}{f}$ $\frac{1}{0.65} = 1.5385$

Power of converging lens = 1.5385 D

ResultsPlus
Examiner Comments

In this case the candidate has confused the near point distance with the focal length. This response scored 1 mark for the use of P=1/f.

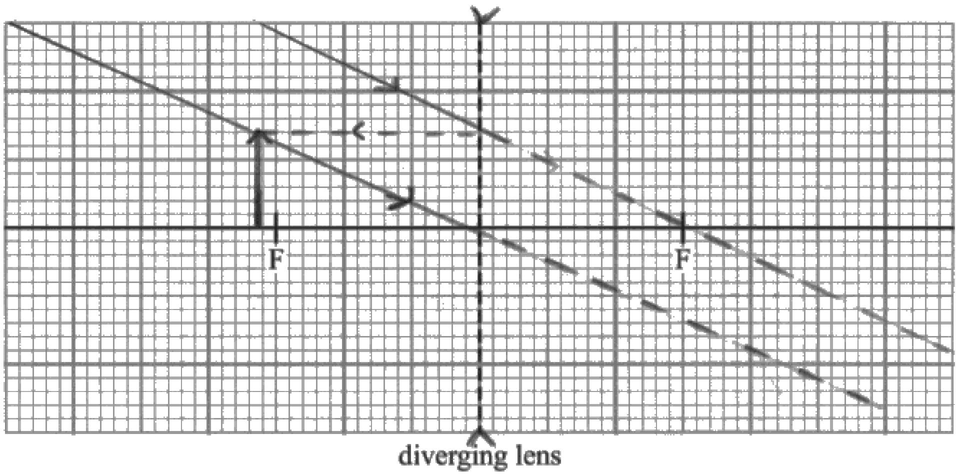
Question 16(c)

This question proved to be quite challenging and few responses scored all 3 marks. In this case, the candidates were asked to draw a ray diagram for a diverging lens to form an image of a distant object. When considering eyesight, a distant object could be several kilometres away, so the incoming rays need to be parallel. This was frequently overlooked and the majority of responses scored 2 marks, for drawing a correct ray diagram for an object which was close to the lens.

(c) A diverging lens can also be used to correct problems with eyesight.

Draw a ray diagram on the axes below to show the formation of the image of a distant object by a diverging lens. F marks the position of each principal focus of the lens. Parallel Rays

(3)



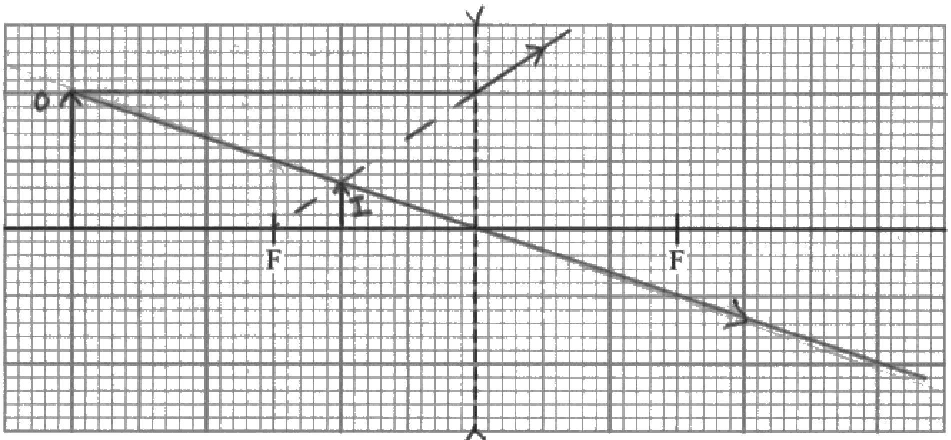
ResultsPlus
Examiner Comments

This response scored all 3 marks. The incoming rays are roughly parallel, arrows have helpfully been included and the image has been represented as an upward pointing arrow on the same side of the lens as the object.

(c) A diverging lens can also be used to correct problems with eyesight.

Draw a ray diagram on the axes below to show the formation of the image of a distant object by a diverging lens. F marks the position of each principal focus of the lens.

(3)



diverging lens

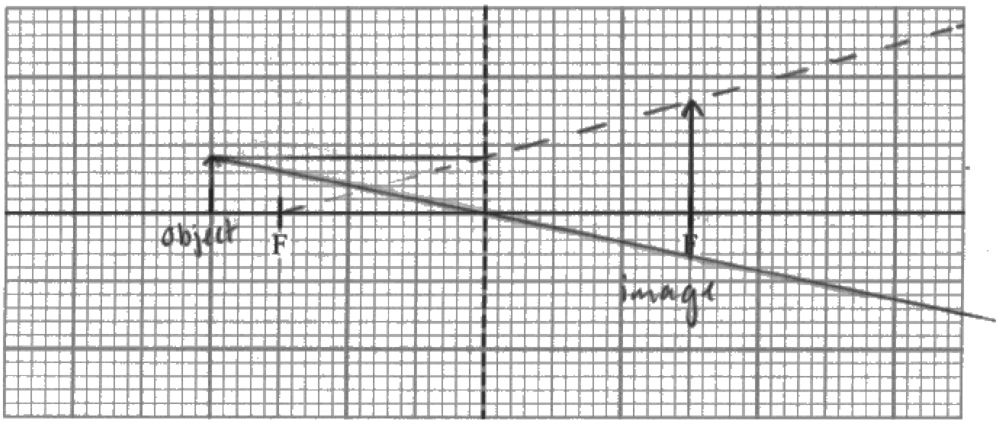
ResultsPlus
Examiner Comments

This response scored marking point 1 for the ray passing diagonally through the intersection of the centre of the lens and the x-axis. It also scored marking point 3, as the image is clearly labelled on the diagram on the same side of the lens as the object. Marking point 2 could not be awarded, as the object is not distant and the incoming rays are not parallel.

(c) A diverging lens can also be used to correct problems with eyesight.

Draw a ray diagram on the axes below to show the formation of the image of a distant object by a diverging lens. F marks the position of each principal focus of the lens.

(3)



diverging lens

ResultsPlus
Examiner Comments

This response scored the first mark only for the ray passing diagonally through the centre of the lens. The incoming rays are not parallel and the image has been formed on the opposite side of the lens to the object. No further marks could be awarded. True score is 1.

Question 17(a)

This question was very well answered with the vast majority of responses scoring all 3 marks for part (a)(i). As it is a show that question, the third mark could be awarded if units had been omitted because the unit is provided in the question. Most of the candidates provided an answer that was at least 1 more significant figure than the show that value. Very rarely was marking point 3 not awarded for not including enough significant figures.

In (a)(ii) the vast majority of responses also scored full marks. Occasionally marking point 2 was not awarded for the omissions of units, or a power of ten error. When no marks were awarded, it was usually because the separation between the Earth and Bennu had not been squared, or an incorrect value of the gravitational constant had been used.

17 The asteroid Bennu is in an approximately circular orbit around the Sun. Scientists consider that Bennu may collide with Earth within the next century.

(a) In 2060 Bennu will be 7.49×10^8 m from the Earth.

(i) Show that the mass of Bennu is about 7.8×10^{10} kg.

mean radius of Bennu = 245 m
average density of Bennu = 1260 kg m^{-3}

(3)

$V = \frac{4}{3}\pi r^3$

$M = V \times \rho$ $\quad V = 61600000$ m

$6.16 \times 10^7 \times 1260$

$= 7.76 \times 10^{10}$ kg //

(ii) Calculate the magnitude of the force F between Bennu and Earth in 2060.

mass of Earth = 5.98×10^{24} kg

(2)

$F = \frac{Gm_1m_2}{r^2} = \frac{6.67 \times 10^{-11} \times 7.8 \times 10^{10} \times 5.98 \times 10^{24}}{(7.49 \times 10^8)^2}$

$= 55457203$

$= 5.5 \times 10^7$ N

$F =$ 5.5×10^7 N

ResultsPlus
Examiner Comments

Here we see recall and use of the formula to calculate the volume of a spherical object, which scores marking point 1. The correctly calculated volume was then multiplied by the density of Bennu, which scored marking point 2. The answer has been given to 3 significant figures, which is one more than the show that value. This response scores all 3 marks.

17 The asteroid Bennu is in an approximately circular orbit around the Sun. Scientists consider that Bennu may collide with Earth within the next century.

100 years

(a) In 2060 Bennu will be 7.49×10^8 m from the Earth.

(i) Show that the mass of Bennu is about 7.8×10^{10} kg.

mean radius of Bennu = 245 m
average density of Bennu = 1260 kg m^{-3}

(3)

$\rho = \frac{m}{V}$

$V = \frac{4}{3}\pi r^3$

$V = \frac{4}{3}\pi(245)^3$
$= 61.6 \times 10^6 \ m^3$

$m = \rho V$

$m = 1260 \times 61.6 \times 10^6$
$= 7.76 \times 10^{10}$ kg
$\approx 7.8 \times 10^{10}$ kg

(ii) Calculate the magnitude of the force F between Bennu and Earth in 2060.

mass of Earth = 5.98×10^{24} kg

(2)

$F = \frac{Gmm}{r^2} = \frac{6.67 \times 10^{-11} \times 5.98 \times 10^{24} \times 7.76 \times 10^{10}}{(7.49 \times 10^8)^2} = 5.5 \times 10^6$ N

$F =$ 5.5×10^6 N

ResultsPlus
Examiner Comments

In part (i) we can see clear working to award all 3 marks. In part (ii) even though the working appears to be correct, there is a power of ten error, which means marking point 2 cannot be awarded.

17 The asteroid Bennu is in an approximately circular orbit around the Sun. Scientists consider that Bennu may collide with Earth within the next century.

(a) In 2060 Bennu will be 7.49×10^8 m from the Earth.

(i) Show that the mass of Bennu is about 7.8×10^{10} kg.

mean radius of Bennu = 245 m
average density of Bennu = 1260 kg m^{-3}

$1260 = \frac{m}{V}$

$\cancel{4\pi r^2}$

$\frac{4}{3}\pi r^3$

(3)

$\frac{mv^2}{r} = \frac{Gmm}{r^2}$

$v^2 = Gm$

$1260 = \frac{m}{\frac{4}{3} \times \pi \times 245^3}$

$m = 7.76 \times 10^{10} \approx 7.8 \times 10^{10}$ kg

(ii) Calculate the magnitude of the force F between Bennu and Earth in 2060.

mass of Earth = 5.98×10^{24} kg

(2)

$\frac{(6.67 \times 10^{-11}) \times (5.98 \times 10^{24}) \times (7.76 \times 10^{10})}{7.49 \times 10^8} = 4.1 \times 10^{16}$

F = 4.1×10^{16} N

ResultsPlus
Examiner Comments

Here we see in part (i) the candidate has combined all of their working in just one step to correctly calculate the mass of Bennu. They have given their answer to 3 significant figures, so all 3 marks are awarded. In part (ii) they have correctly substituted all of the values into the equation, but they have not squared the separation, so no marks can be awarded.

ResultsPlus
Examiner Tip

If it is a show that question, always include at least 1 more significant figure than the value given in the question and substitute all values fully into the equations. When a calculation question is not a show that question, units will be required along with the correct answer to score the final mark, unless it is given in the question.

Question 17(b)

This question was generally well answered with a significantly large proportion of candidates scoring all 4 marks. However, when full marks were not awarded, often it was for not substituting values into equations, or incorrect algebra. Occasional unit omission also lost marking point 4 in some responses.

(b) The orbital time of Bennu around the Sun is 1.17 years.

Calculate the mass of the Sun.

average distance of Bennu from the Sun = 1.70×10^{11} m
mass of Bennu = 7.8×10^{10} kg
1 year = 3.15×10^{7} s

(4)

$\frac{mv^2}{r} = \frac{GMm}{r^2}$ $\quad v^2 = \frac{GM}{r}$

$\left(\frac{2\pi r}{T}\right)^2 = \frac{GM}{r}$

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

$M = \frac{4\pi^2 r^3}{GT^2}$

$M = \frac{4\pi^2 \times (1.7 \times 10^{11})^3}{6.67 \times 10^{-11} \times (3.15 \times 10^7 \times 1.17)^2}$

$M = 2.14 \times 10^{30}$

Mass of Sun = 2.14×10^{30} kg

ResultsPlus
Examiner Comments

Here we see the candidate has used correct algebra to derive a correct equation to calculate mass. They have substituted in correct values and the final answer is correct with the correct unit included. This scored all 4 marks.

(b) The orbital time of Bennu around the Sun is 1.17 years.

Calculate the mass of the Sun. m_2

r average distance of Bennu from the Sun = 1.70×10^{11} m
m mass of Bennu = 7.8×10^{10} kg
1 year = 3.15×10^7 s

(4)

$T = \frac{2\pi}{w} = 1.17 \times 3.15 \times 10^7$

$F = \frac{Gm_1 m_2}{r^2}$ $F = mrw^2$ $w = \frac{2\pi}{T}$

$F = mr\left(\frac{2\pi}{T}\right)^2$

$\frac{G\cancel{m_1} m_2}{r^{\cancel{2}}} = \cancel{m}\cancel{r}\left(\frac{2\pi}{T}\right)^2$ $= \frac{Gm}{r} = \frac{2\pi}{T}^2$

$m = \cancel{\frac{2\pi^2 r^3}{TG}}$ $\frac{r}{G} \times \left(\frac{2\pi}{T}\right)^2 = 7.6 \times 10^7$

Mass of Sun = 7.6×10^7 kg

ResultsPlus
Examiner Comments

This response has used correct algebra to derive a correct equation to calculate the mass of the Earth. However, as they have not substituted in any values and the final answer is incorrect, it is not possible to award any marks.

ResultsPlus
Examiner Tip

Candidates should always be encouraged to show full working and correctly substitute values into equations.

Question 18(a)

Here the candidates were required to complete the decay equation for the beta minus decay of caesium. MP1 and MP2 were awarded for the top and bottom row being correct respectively. This question was very well answered in general, with the vast majority of candidates scoring both marks. Occasionally MP2 was not scored as the candidate had confused the decay with beta plus decay. There were also some responses where the candidate thought that alpha decay was taking place, in which case this lost both marks.

18 Glaciers are massive bodies of slowly moving ice. Over time, a fine sediment forms on the surface of a glacier. The sediment contains radioactive isotopes.

Caesium-137, ^{137}Cs, is a common radioisotope found in the sediment.

(a) Complete the following nuclear equation to represent the decay of caesium.

(2)

$$^{137}_{55}\text{Cs} \rightarrow \,^{137}_{56}\text{Ba} + \,^{0}_{-1}\beta^{-} + \,^{0}_{0}\overline{\nu}_e$$

ResultsPlus
Examiner Comments

Both the top and bottom row are correct, so this scores 2 marks.

ResultsPlus
Examiner Tip

Here we see a beta minus particle, which is an electron. This means beta minus decay is taking place. The fact that an antineutrino is produced with the notation e on it is further evidence for beta minus decay.

18 Glaciers are massive bodies of slowly moving ice. Over time, a fine sediment forms on the surface of a glacier. The sediment contains radioactive isotopes.

Caesium-137, ^{137}Cs, is a common radioisotope found in the sediment.

(a) Complete the following nuclear equation to represent the decay of caesium.

(2)

$$^{137}_{55}\text{Cs} \rightarrow \, ^{137}_{54}\text{Ba} + \, ^{0}_{-1}\beta^{-} + \, ^{0}_{0}\overline{\nu}_{e}$$

ResultsPlus
Examiner Comments

This response scores MP1 as we can see the top row is correct. However, in the bottom row we see 54 - 1, which does not equal 55. So, this response scored 1 mark only.

ResultsPlus
Examiner Tip

The sum of the right-hand side of the equation must be equal to the left-hand side.

Question 18(b)

In part (i) candidates were required to calculate the decay constant, then use this with the equation for activity to calculate the number of atoms. The third mark was for the correct answer and as it was the number of atoms, no unit was required. The vast majority of candidates scored full marks in this calculation.

Part (ii) was also generally very well answered, with the majority of responses scoring full marks. When this wasn't the case it was because the candidate had calculated the time taken for the number of atoms present to drop to 10%, not by 10%. This meant they could score MP1 if they had used the exponential decay equation with 10%, as this is dimensionally correct. However, it did result in the incorrect answer, so MP2 could not be scored.

(b) The concentration of ^{137}Cs on a Norwegian glacier was investigated.

half-life of $^{137}Cs = 9.5 \times 10^8$ s

(i) The activity of ^{137}Cs was determined to be 2.5×10^4 Bq per kg of sediment.

Calculate the number of atoms of ^{137}Cs in 1 kg of sediment.

(3)

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

$N = \frac{A}{\lambda}$

$= \frac{A\, t_{1/2}}{\ln 2} = \frac{2.5 \times 10^4 \times 9.5 \times 10^8}{\ln 2}$

$= 3.43 \times 10^{13}$

Number of atoms of ^{137}Cs = 3.43×10^{13}

(ii) Calculate the time taken for 10% of the ^{137}Cs atoms to have decayed.

↳ 90% left.

(2)

$0.9 = e^{-\lambda t}$

$-\ln 0.9 = \lambda t$

$t = \frac{-\ln 0.9}{\lambda} = -\frac{\ln 0.9}{\ln 2} \times 9.5 \times 10^8 = 1.44 \times 10^8$ seconds.

Time taken = 1.44×10^8 seconds

ResultsPlus
Examiner Comments

Part (i) scores all 3 marks, correct values have been substituted into the correct equations and the final answer is correct. Part (ii) also scores full marks, as the candidate has realised that 90% of the atoms will be remaining and used this correctly in the exponential decay equation. They have included the correct unit with the correct answer.

(b) The concentration of ^{137}Cs on a Norwegian glacier was investigated.

half-life of $^{137}Cs = 9.5 \times 10^8$ s $\frac{1}{2}t$

(i) The activity of ^{137}Cs was determined to be 2.5×10^4 Bq per kg of sediment.

Calculate the number of atoms of ^{137}Cs in 1 kg of sediment.

(3)

$\lambda = \frac{\ln 2}{\frac{1}{2}t} = \frac{\ln 2}{(9.5\times10^8)} = 7.296286111\times10^{-10}$

$A = \lambda N \quad N = \frac{A}{\lambda}$

$\frac{(2.5\times10^4)}{(7.3\times10^{-10})} = 3.426400722\times10^{13}$ ~~$A = (7.3\times10^{-10})$~~

Number of atoms of ^{137}Cs = 3.43×10^{13}

(ii) Calculate the time taken for 10% of the ^{137}Cs atoms to have decayed.

(2)

$10\% =$

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

$\ln \frac{N}{N_0} = -\lambda t$

$\ln \frac{1}{0.1} = \lambda t$

$t = \frac{1}{\lambda} \ln \frac{1}{0.1}$

$= \left(\frac{1}{7.3\times10^{-10}}\right)\left(\ln \frac{1}{0.1}\right) = 3,155,831,640$ seconds

3,155.

Time taken = 3,155,831,640 s

ResultsPlus
Examiner Comments

Part (i) scores all 3 marks. In part (ii) we can see the candidate has calculated the time for 90% of the atoms to decay, so scored MP1 only.

ResultsPlus
Examiner Tip

When considering this type of question it is important to think about what percentage of atoms are remaining.

(b) The concentration of ^{137}Cs on a Norwegian glacier was investigated.

half-life of $^{137}Cs = 9.5 \times 10^8$ s

(i) The activity of ^{137}Cs was determined to be 2.5×10^4 Bq per kg of sediment.

Calculate the number of atoms of ^{137}Cs in 1 kg of sediment.

(3)

$\lambda = \frac{\ln 2}{9.5\times10^8} = 7.296\times10^{-10}$

$A = \lambda N$

$\frac{2.5\times10^4}{7.296\times10^{-10}} = 3.426\times10^{13}$

Number of atoms of ^{137}Cs = 3.426×10^{13}

(ii) Calculate the time taken for 10% of the ^{137}Cs atoms to have decayed.

(2)

~~3.426~~ ~~3.426×10^13 × 0.1~~ $\frac{\ln\left(\frac{N_0}{N_0}\right)}{-\lambda} = t$

~~3.426×10^13 − 3.426×10^13~~

$\ln\left(\frac{3.426\times10^{13}\times0.9}{3.426\times10^{13}}\right) = (-7.296\times10^{-10})\ t$

$t = 144408601.55 = 1.44\times10^8$

Time taken = 1.44×10^8

ResultsPlus
Examiner Comments

Here we see part (i) scores all 3 marks. In part (ii) we can see that the candidate has calculated 90%of the number of atoms and has correctly calculated the answer. However, due to omitting the unit the second mark cannot be awarded.

ResultsPlus
Examiner Tip

Unless it is a show that question, always include units, unless they are given in the answer line.

Question 19(a)-(b)i

Another well answered question in general, with the vast majority of candidates scoring full marks on part (i) and at least 4 marks on part (ii). There were many responses which scored full marks, although there were various routes for candidates to take.

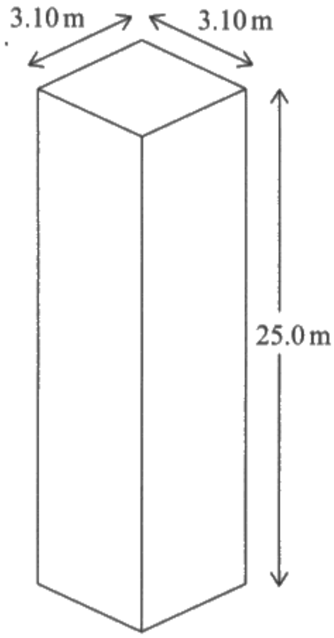
In part (b)(i) marking points 1 and 5 were usually awarded for calculating the power of the sunlight using I=P/A and then using E=Pt to calculate the energy supplied by the sun. Marking points 2, 3 and 4 could be awarded in a variety of ways. Often candidates worked out 1% of the total mass, which was calculated in part (i), then used this with the formula for specific heat capacity and the formula for latent heat to determine the amount of energy needed to melt 1% of the ice. If they then went to make a comparison with the correct energy supplied, with a valid conclusion, full marks were generally awarded.

Equally if the candidate had correctly worked out the time to melt 1% and compared this to 12 hours with a conclusion, full marks were awarded. Some candidates added the equations for specific heat capacity and latent heat and put these equal to the energy supplied by the sunlight. They then worked out the percentage of the total mass melted and compared it to 1%, with a correct conclusion, this could also score full marks.

19 The photograph shows a giant ice sculpture of the Elizabeth Tower (Big Ben). The ice sculpture was installed in St Pancras station in London in 2009.

(Source: © Skye Hohmann / Alamy Stock Photo)

The ice sculpture can be approximated as a regular cuboid, as shown below.



(a) Show that the mass of the ice sculpture is about 2.2×10^5 kg.

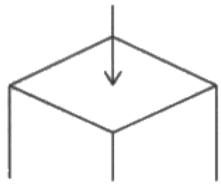
density of ice = $920\,\text{kg}\,\text{m}^{-3}$

(2)

$\rho = \frac{m}{V}$ $\quad 920 \times 3.1 \times 3.1 \times 25 = m$

$m = 2.21 \times 10^5$ Kg

(b) (i) It is claimed that 1% of the ice would melt if the ice sculpture were in direct sunlight continuously for 12 hours. Assume that radiation, of intensity I, from the Sun is directly incident upon the top of the sculpture, as shown below.



Deduce whether this claim is correct.

initial temperature of ice sculpture = –20 °C
intensity of the Sun = 1350 W m^{-2}
specific heat capacity of ice = 2.09×10^3 J kg^{-1} K^{-1}
specific latent heat of ice = 3.34×10^5 J kg^{-1}

$P = \frac{E}{t}$

(6)

$1350 = \frac{P}{A}$ $\cancel{\Delta E = 20m \times 2.09\times10^3 + 3.34\times10^5 m}$

$1350At = E$ To melt 1% of the ice,

$A = 3.1 \times 3.1 = 9.61$, $t = 12 \times 60 \times 60 = 43200$ mass $= \frac{2.2\times10^5}{100} = 2200\,\text{Kg}$

$E = 43200 \times 1350 \times 9.61$ $\Delta E = 20 \times 2.09\times10^3 \times 2200 + 2200 \times 3.34\times10^5$

$= 5.6 \times 10^8$ J $= 8.2676 \times 10^8$ J

As $8.3\times10^8 > 5.6\times10^8$, energy required to melt 1% of the ice not ~~full~~ provided by sunlight in 12 hours, so claim incorrect.

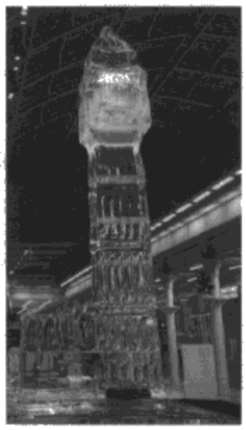
ResultsPlus
Examiner Comments

In part (i) the candidate has combined the 2 equations, correctly substituted in all of the relevant values and calculated the correct answer. They have included units although, in this case, it isn't necessary as it is a show that question. In part (ii) we can see that they have correctly calculated the energy required to melt 1% of the ice and compared this to the energy supplied. The candidate has concluded that the claim is incorrect. Even though they did not include units in their comparison, these have been provided in the working above it, so this scores all 6 marks.

ResultsPlus
Examiner Tip

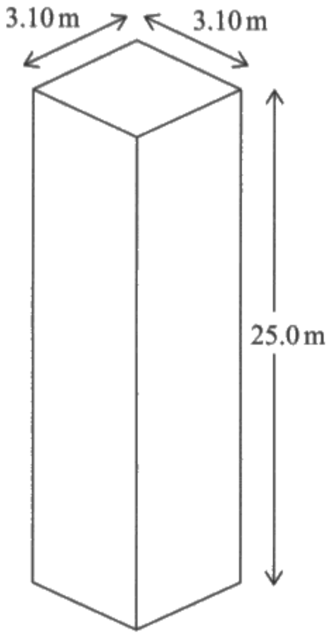
When being asked to deduce something, there is always a mark for a mathematical comparison of the values and a conclusion, so in this case if the claim was correct.

19 The photograph shows a giant ice sculpture of the Elizabeth Tower (Big Ben). The ice sculpture was installed in St Pancras station in London in 2009.



(Source: © Skye Hohmann / Alamy Stock Photo)

The ice sculpture can be approximated as a regular cuboid, as shown below.



(a) Show that the mass of the ice sculpture is about 2.2×10^5 kg.

density of ice = $920\,\text{kg}\,\text{m}^{-3}$

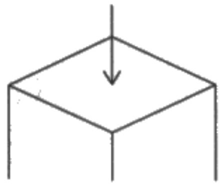
(2)

$3.1 \times 3.1 \times 25 = 240.25\,m^3$

$240.25 \times 920 = 221\,030\,kg$

$\approx 2.2 \times 10^5\,kg$

(b) (i) It is claimed that 1% of the ice would melt if the ice sculpture were in direct sunlight continuously for 12 hours. Assume that radiation, of intensity I, from the Sun is directly incident upon the top of the sculpture, as shown below.



Deduce whether this claim is correct.

initial temperature of ice sculpture = –20 °C
intensity of the Sun = $1350\,W\,m^{-2}$
specific heat capacity of ice = $2.09 \times 10^{3}\,J\,kg^{-1}\,K^{-1}$
specific latent heat of ice = $3.34 \times 10^{5}\,J\,kg^{-1}$

(6)

$I \times A = P$

$1350 \times 3.1^{2} = 12973.5\ W$

$P \times t = E$

$12973.5 \times 12 \times 60^{2} = 560\,455\,200\ J$

$\Delta E = mc\Delta\theta$

$\Delta E = 2.2\times10^{5} \times 2.09\times10^{3} \times 20$

$\Delta E = 9196\,000\,000\ J$

$\Delta E = L\Delta m$

$\Delta E = 3.34\times10^{5} \times 0.01 \times 2.2\times10^{5}$

$= 734\,800\,000$

$(9196\,000\,000 + 734\,800\,000) > 560\,455\,200$ ∴ claim is incorrect, as less than 1% of ice melts.

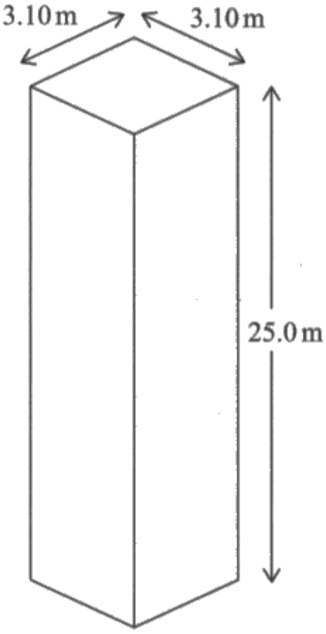
ResultsPlus
Examiner Comments

Part (i) shows full working and a correct answer so scores both marks. In part (ii) the candidate has attempted to calculate the energy required to melt 1% of the ice, but they have not used 1% of the mass in the equation for specific heat capacity. Therefore, the final answer in the comparison is not correct, so MP6 cannot be awarded. This scored 5 marks.

19 The photograph shows a giant ice sculpture of the Elizabeth Tower (Big Ben). The ice sculpture was installed in St Pancras station in London in 2009.

(Source: © Skye Hohmann / Alamy Stock Photo)

The ice sculpture can be approximated as a regular cuboid, as shown below.



(a) Show that the mass of the ice sculpture is about 2.2×10^5 kg.

density of ice = $920\,\text{kg}\,\text{m}^{-3}$

(2)

$d = \frac{m}{V}$ $V = 3.1^2 \times 25 = 240.25$

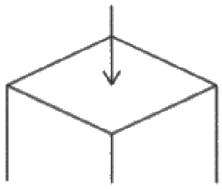
$920 \times 240.25 = m$

$= 221030$

$= 2.21 \times 10^5$ kg

(b) (i) It is claimed that 1% of the ice would melt if the ice sculpture were in direct sunlight continuously for 12 hours. Assume that radiation, of intensity I, from the Sun is directly incident upon the top of the sculpture, as shown below.

$I = 1350\ \mathrm{W\,m^{-2}}$



Deduce whether this claim is correct.

$E = m_c\theta + mL$

initial temperature of ice sculpture = –20 °C
intensity of the Sun = $1350\ \mathrm{W\,m^{-2}}$
specific heat capacity of ice = $2.09 \times 10^3\ \mathrm{J\,kg^{-1}\,K^{-1}}$
specific latent heat of ice = $3.34 \times 10^5\ \mathrm{J\,kg^{-1}}$

(6)

$I = \frac{P}{A}$ $\quad P = \frac{E}{t}$ $\quad \cancel{E = 22.2105 \times 2.09\times10^3 + m \times 3.34\times10^5}$

$P \times t = E$ $\quad = 221030 \times (2.09\times10^3) \times (20) + m(3.34\times10^5)$

$I \times A \times t = E$

$E = 1350 \times 3.1^2 \times 12 \times 60 \times 60$

$= 560455200 = \cancel{92390540000 + m(3.34\times10^5)}$

$5.6\times10^8 = 375800\ m$

$m = 1491.4$

$\frac{1491.4}{221030} \times 100 = 0.67\% \approx 1\%$

∴ The claim is correct

ResultsPlus
Examiner Comments

Here is another clear example of a response which scored full marks in both parts. The candidate has calculated the energy supplied by the incident radiation and then used this to calculate the mass which will melt. They then go on to calculate the percentage of the total mass which equals 0.67% and stated that it is roughly equal to 1%, so the claim is correct. The true score is 6 marks for part (ii).

Question 19(b)ii

In this question candidates were asked to give 2 reasons why their analysis of the situation may be incorrect. In general, it was well attempted, with the majority of candidates scoring at least one mark. Where marks were not awarded this was occasionally due to saying energy would be transferred from the ice to the surroundings rather than energy being transferred to the ice from the surroundings.

(ii) Give **two** reasons why your analysis of the situation may be incorrect.

(2)

• ~~[illegible]~~

~~[illegible]~~.

• The intensity of light is likely to change ~~throughout~~ throughout the day.

• The air temperature will also heat up the ice making it melt quicker so less energy

(Total for Question 19 = 10 marks)

ResultsPlus
Examiner Comments

This scored the first marking point for the idea that surrounding air will also transfer energy to the ice. It also scored the second marking point for the idea that the intensity of light will not be constant.

(ii) Give **two** reasons why your analysis of the situation may be incorrect.

(2)

inconsistent intensity of sunlight (clouds, time of day) may affect the results.

ResultsPlus
Examiner Comments

This scored the second marking point for the idea that the radiation from the sun will not be constant. However, no further response has been provided. This scored 1 mark.

(ii) Give **two** reasons why your analysis of the situation may be incorrect.

(2)

Some heat may be dissipated to the surroundings.
Some thermal energy is used to break bonds to change state.

ResultsPlus Examiner Comments

Here we cannot award marking point 1, as the idea of heat being transferred to the ice from the surroundings is incorrect. There is no further creditworthy response, so this scores 0 marks.

Question 20(a)

In this question candidates were required to calculate the stress at the base of each column. The question was well answered in general, with the vast majority of candidates scoring at least 3 marks. There was a significant proportion of responses which scored all 5 marks. Where full marks were not awarded, this was at times due to unit omission, or incorrect units. Responses where candidates had used 16 more than once also could not score full marks.

20 The photograph shows the Petronas Twin Towers in Kuala Lumpur, which are the world's tallest twin buildings.

(Source: © saiko3p/Shutterstock)

(a) Each tower is supported by 16 cylindrical concrete columns.

Calculate the stress at the base of each cylindrical concrete column.

mass of each tower = 3.0×10^8 kg
diameter of each column = 2.4 m

(5)

$$\text{Stress} = \frac{\text{Force}}{\text{Area}} \qquad \text{Force} = \frac{3 \times 10^8 + 9.81}{16}$$

$$\frac{\frac{3 \times 10^8 + 9.81}{16}}{(2.4 \div 2)^2 \pi} = 40\ 659\ 114.37$$

Stress at the base of each column = 4.07×10^7 N m^{-2}

ResultsPlus
Examiner Comments

This response scored all 5 marks. We can see that they have calculated the weight of each tower correctly to determine the force. This has been divided by the correct area and also been divided by 16. Correct units have been included, although Pa is also accepted.

20 The photograph shows the Petronas Twin Towers in Kuala Lumpur, which are the world's tallest twin buildings.

(Source: © saiko3p/Shutterstock)

(a) Each tower is supported by 16 cylindrical concrete columns.

Calculate the stress at the base of each cylindrical concrete column.

mass of each tower = 3.0×10^8 kg
diameter of each column = 2.4 m

(5)

Radius of each column = 1.2 m

Area of each column = $\pi \times 1.2^2 = 4.52$ m^2

Total area = $16 \times 4.52 = 72.32$ m^2

$\sigma = \frac{F}{A}$

$\sigma = \frac{3 \times 10^8 \times 9.81}{72.32} = 4.07 \times 10^7$

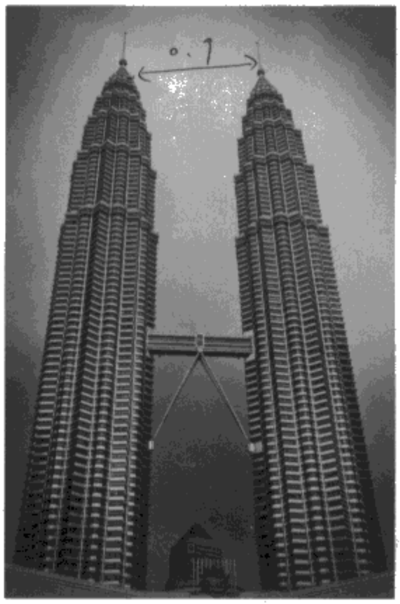
$4.07 \times 10^7 \div 16 = 2.54 \times 10^6$

Stress at the base of each column = 2.54×10^6 Nm^{-2}

ResultsPlus
Examiner Comments

Here was can see that the candidate has carried out the necessary steps to arrive at the correct answer. They then go on to divide this by 16, so MP5 cannot be awarded. This scored 4 marks.

20 The photograph shows the Petronas Twin Towers in Kuala Lumpur, which are the world's tallest twin buildings.



(Source: © saiko3p/Shutterstock)

(a) Each tower is supported by 16 cylindrical concrete columns.

Calculate the stress at the base of each cylindrical concrete column.

mass of each tower = 3.0×10^8 kg
diameter of each column = 2.4 m

(5)

$\cancel{\sigma = \frac{F}{A}}$ $\quad r = \frac{d}{2} = \frac{2.4}{2} = 1.2$ m

$A = \pi r^2 = 1.2^2 \pi = 4.5$ m^2

$F = mg = 3 \times 10^8 \times 9.81 = 2.94 \times 10^9$ N

$\sigma = \frac{F}{A} = \frac{2.94 \times 10^9}{4.5} = 6.5 \times 10^8$ kg m^{-1} s^{-2}

Stress at the base of each column = 6.5×10^8 kg m^{-1} s^{-2}

ResultsPlus
Examiner Comments

This response scores marking points 1, 2 and 3. However, they have not used 16, so the final answer is incorrect. True score is 3 marks.

Question 20(b)i

This question was generally well answered, with a significant proportion of candidates scoring all 3 marks. The vast majority of candidates were able to be awarded the first marking point for the calculation of the angular velocity. In order to score the second mark use of v=-Aω sin ωt was required with sin ωt being equal to 0. The third mark was for the correct answer with correct units.

(b) Tall buildings sway in the wind. The design of the Petronas Towers permits safe movement of the towers.

(i) The towers were designed to permit a maximum horizontal displacement of 0.90 m at the top of the towers. The natural frequency of each tower is 0.17 Hz.

Calculate the maximum velocity at the top of one of the towers when the tower is oscillating at its natural frequency.

(3)

$V_{max} = A\omega$

$= 0.90 \times 2\pi \times 0.17 = 0.96 ms^{-1}$

Maximum velocity at the top of the tower = $0.96 ms^{-1}$

ResultsPlus
Examiner Comments

This candidate has combined both steps, to arrive at the correct answer and has included correct units. This scores all 3 marks.

(b) Tall buildings sway in the wind. The design of the Petronas Towers permits safe movement of the towers.

(i) The towers were designed to permit a maximum horizontal displacement of 0.90 m at the top of the towers. The natural frequency of each tower is 0.17 Hz.

Calculate the maximum velocity at the top of one of the towers when the tower is oscillating at its natural frequency.

(3)

$V_{max} = A\omega \qquad \omega = 2\pi f \qquad x = A \cos\omega t$

$= 0.9 \times 2\pi \times 0.17 = 0.96 \qquad 0.9 = A$

Maximum velocity at the top of the tower = $0.96 ms^{-2}$

ResultsPlus Examiner Comments

Here we see correct working leading to the correct answer. However, the unit is incorrect. Therefore, in this case the third mark cannot be awarded.

ResultsPlus Examiner Tip

Always be sure to include correct units where required. This is on all questions that do not give the unit in the answer line, with the exception of show that questions, where the unit is provided in the question.

(b) Tall buildings sway in the wind. The design of the Petronas Towers permits safe movement of the towers.

(i) The towers were designed to permit a maximum horizontal displacement of 0.90 m at the top of the towers. The natural frequency of each tower is 0.17 Hz.

Calculate the maximum velocity at the top of one of the towers when the tower is oscillating at its natural frequency.

(3)

$\omega = 2\pi f = 2\pi\, 0.17 = 1.07\ \text{rad s}^{-1}$

$\cancel{2\pi}$ $T = \frac{1}{f} = \frac{1}{0.17} = 5.88$

$v = -A\omega \sin \omega t$

$-0.90 \times 1.07 \sin(1.07)\, 5.88$

$= 0.105\ \text{ms}^{-1}$

Maximum velocity at the top of the tower = $0.11\ \text{ms}^{-1}$

ResultsPlus
Examiner Comments

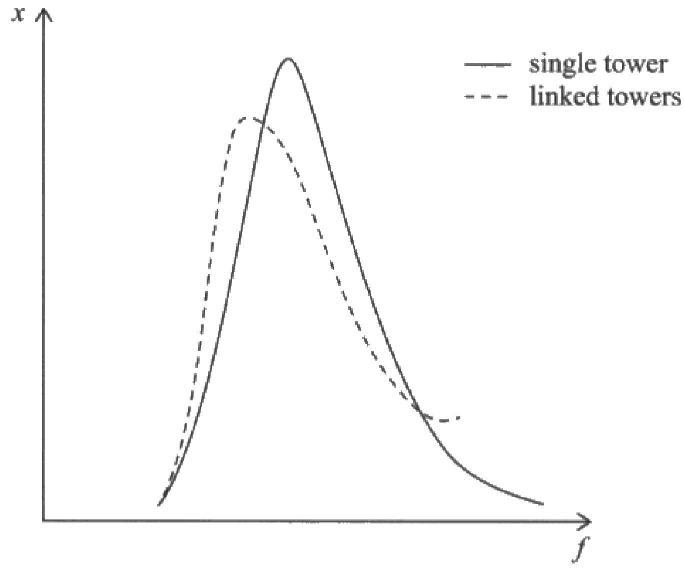
Here MP1 is awarded for correctly calculating the angular velocity. However, sin ωt is not equal to 0, so this scores no further marks.

Question 20(b)ii

This question proved to be fairly challenging, and relatively few responses that scored full marks were seen. The question is about the effects of resonance. In which case, we need to see responses which refer to the natural frequency of the oscillating system. Marking points 2 and 4 were frequently scored for reference to resonance and damping respectively. When marking points 1 and 3 were not awarded, this was often due to the omission of the term natural in natural frequency.

(ii) The twin towers were linked together to improve the response of the building to strong winds.

The graph below shows how the maximum displacement x varies with the frequency f for a single tower and for two linked towers.



Explain the behaviour of a single tower compared with the behaviour of the linked towers.

(3)

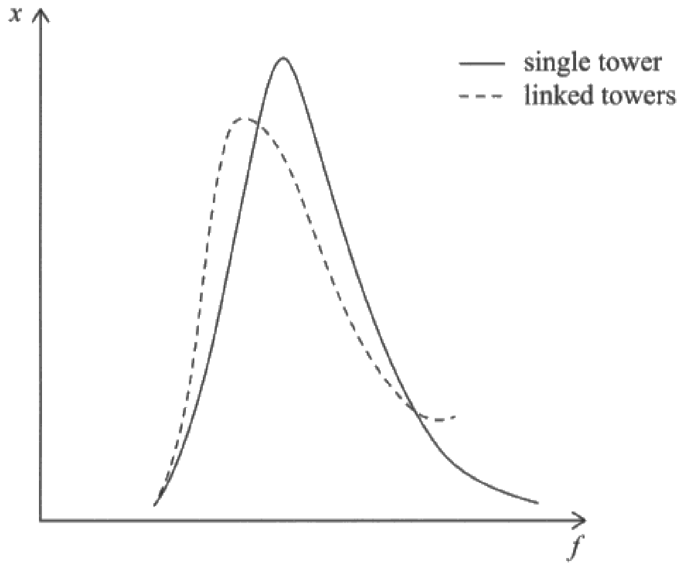
The linked towers produce less displacement for a higher frequency, as ~~the~~ resonance occurs at a lower natural frequency. This is because the oscillations of the linked towers are ~~at~~ more damped than the single tower. This means more energy is removed from the towers to the surroundings, which decreases the maximum amplitude the towers oscillate at, compared to the single tower.

ResultsPlus
Examiner Comments

This scores marking point 2, as resonance has been mentioned. Marking point 3 is awarded for the idea of linked towers having a lower displacement at a lower natural frequency. The candidate then goes on to make reference to damping, so scores marking point 4. All 3 marks have been awarded.

(ii) The twin towers were linked together to improve the response of the building to strong winds.

The graph below shows how the maximum displacement x varies with the frequency f for a single tower and for two linked towers.



Explain the behaviour of a single tower compared with the behaviour of the linked towers.

(3)

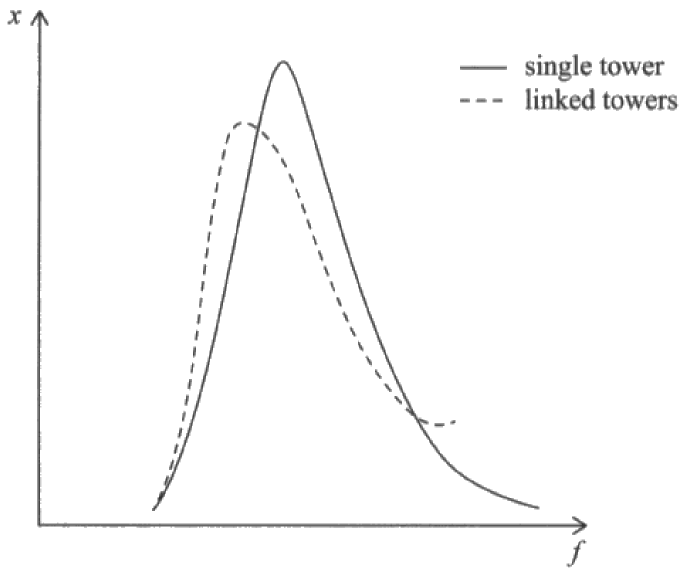
A single tower has a ~~far~~ larger maximum displacement than the linked towers, this ~~it~~ is due to ~~the~~ damping effects ~~of the~~ as more energy is removed from the oscillating system of each tower when they are linked as the other tower absorbs this energy. The natural frequency of the linked towers is ~~therefore~~ lower than the natural frequency of a single tower.

ResultsPlus
Examiner Comments

This response scored marking point 3 and 4. They have not mentioned resonance or maximum displacement occurs when the tower is forced into oscillations at its natural frequency. This scores 2 marks in total.

(ii) The twin towers were linked together to improve the response of the building to strong winds.

The graph below shows how the maximum displacement *x* varies with the frequency *f* for a single tower and for two linked towers.



Explain the behaviour of a single tower compared with the behaviour of the linked towers.

(3)

- The single tower has a higher value of maximum displacement compared to the linked towers.
- This is due to the fact that damping occurs when the 2 towers are linked
- This damping force reduces the maximum displacement as it transfers energy out of the oscillation and to the surroundings, meaning the oscillation oscillates with a lower ~~amp~~ amplitude

ResultsPlus
Examiner Comments

This response scored the fourth marking point only for making reference to damping. There is no reference to resonance or natural frequency, so no further marks can be awarded.

Question 21(a)

In this question candidates were asked to state what is meant by absolute zero. This proved to be quite challenging. The definition needs to use the term molecules or atoms. Often the mark was not awarded, as the response used the term 'particles'. When considering thermal physics, the term 'particles' is not accepted, as it could refer to other substances such as dust. The lowest temperature possible was awarded the mark, and this was quite frequently seen.

21 All objects with a temperature above absolute zero emit a spectrum of electromagnetic radiation.

(a) State what is meant by absolute zero.

(1)

The temperature at which the Kinetic energy of molecules is 0, and when pressure and volume ~~of~~ of a gas = 0.

ResultsPlus
Examiner Comments

This response scored the mark for "kinetic energy of the molecules is zero."

21 All objects with a temperature above absolute zero emit a spectrum of electromagnetic radiation.

(a) State what is meant by absolute zero.

(1)

the lowest possible temperature at which there is no kinetic energy

ResultsPlus
Examiner Comments

This response scored the mark on the additional guidance from the mark scheme. The lowest temperature possible.

21 All objects with a temperature above absolute zero emit a spectrum of electromagnetic radiation.

(a) State what is meant by absolute zero.

(1)

Temperature in Kelvin is 0 so particles have no kinetic energy and do not move.

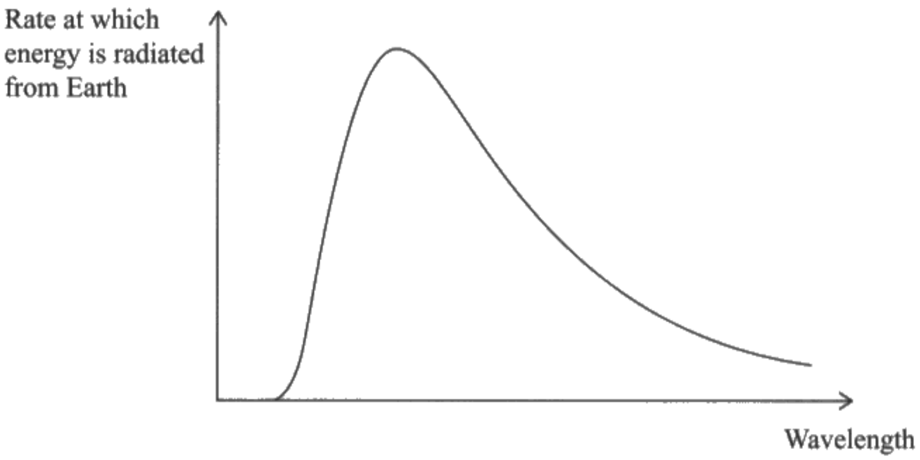
ResultsPlus
Examiner Comments

This response did not score the mark, as the candidate has used the term 'particles' rather than 'atoms' or 'molecules'.

Question 21(b)

This question tested the understanding of black body radiators. Candidates found this question challenging, although the majority were able to access some marks. There were some excellent examples scoring all 4 marks.

(b) The graph shows how the intensity of radiation emitted by the Earth varied with wavelength in 2020.



Explain the differences between this graph and a graph representing the emission of radiation by the Earth in 2050. Assume that the average global temperature increases over time.

(4)

The earth is acting as a black body radiator. ~~Maximum~~ wavelength ~~emitting highest radiated~~ at which there is highest energy radiated will ~~increase~~ decrease as ~~$\lambda_{max}T = 2.898$~~

$\lambda_{max}T = 2.898 \times 10^{-3}$, T = temperature , $\lambda_{max} = \frac{2.898 \times 10^{-3}}{T}$

So increase in temperature mean graph will shift left.

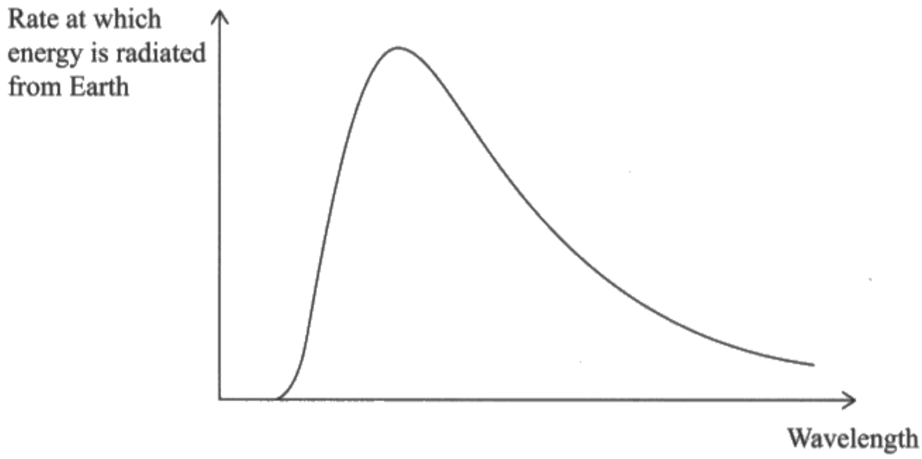
graph will also be stretched upwards as rate of energy radiation = (Power) will increase as L (Power) luminosity $\propto$ $= \sigma A T^4$ where σ and A are constant

So increasing T will increase peak of curve by 16 times as much.

ResultsPlus
Examiner Comments

Here we see clear reference to Wein's law, which scored the fourth marking point. "The graph will shift left" scored marking point 3. "The graph will be stretched upwards" gave the idea that the peak will increase and scored marking point 1. Finally, reference to Stefan law scored marking point 2. This scores all 4 marks.

(b) The graph shows how the intensity of radiation emitted by the Earth varied with wavelength in 2020.



Explain the differences between this graph and a graph representing the emission of radiation by the Earth in 2050. Assume that the average global temperature increases over time.

(4)

• $T\lambda_{max} = 2.898\times10^{-3}$ so $\lambda_{max} = \frac{2.891\times10^{-3}}{T}$ so increasing temperature of earth means wavelength at which peak emission occurs, λ_{max} decreases. Temperature in 2050 is higher.

• So peak of graph in 2050 ~~is lower~~ occurs at a smaller wavelength.

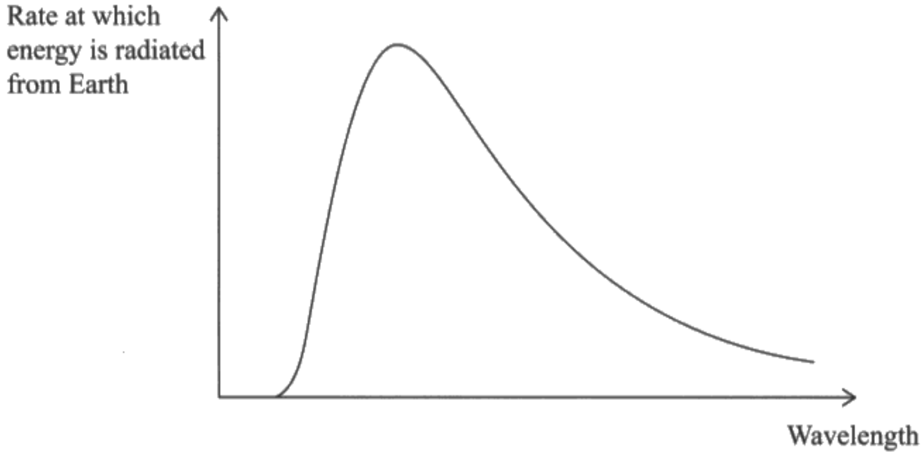
• temperature is higher so overall more energy is radiated.

↳ so peak of graph is higher and graph is overall less spread out.

ResultsPlus
Examiner Comments

This scored MP3 and MP4 for quoting Wein's law and saying the peak wavelength will be smaller. The idea that the peak is higher is also evident, so MP1 is awarded. However, there is no reference to Stefan's law or that temperature is proportional to T to the power of 4. This response scores 3 marks.

(b) The graph shows how the intensity of radiation emitted by the Earth varied with wavelength in 2020.



Explain the differences between this graph and a graph representing the emission of radiation by the Earth in 2050. Assume that the average global temperature increases over time.

(4)

with the increase in avg global temperature, this graph would shift left, as wein's law states that temperature is inversely proportional to ~~the~~ maximum wavelength, as temperature increases wavelength decreases

$\lambda_{max} T = 2.898 \times 10^{-3}$

$\lambda_{max} = \frac{2.898 \times 10^{-3}}{T}$ $\lambda_{max} \propto \frac{1}{T}$

ResultsPlus
Examiner Comments

This scored marking point 3 and 4 only. There is no reference to Stefan's law, or that the peak will increase.

Question 21(c)

This question was generally well answered with the vast majority of responses scoring at least 2 marks for calculating the constant for all 3 stars. It was less common to see all 3 marks being scored due to candidates not comparing the values to the Wein's law constant or not stating that the calculated values are constant or similar to one another.

(c) At the end of the 19th century, Wien investigated the radiation emitted by hot objects and formulated a law.

The table shows data for some stars.

Star	λ_{max} / nm	T / K
Bellatrix	132	21 500
Rigel	245	11 600
Sirius	287	9910

Deduce whether Wien's law is confirmed by this data.

(3)

$\lambda_{max} \cdot T = 2.898 \times 10^{-3}$

Bellatrix: ① $132 \times 10^{-9} \times 21\,500 = 2.838 \times 10^{-3}$ $\approx 2.84 \times 10^{-3}$

Rigel ②: $245 \times 10^{-9} \times 11600 = 2.842 \times 10^{-3}$ $\approx 2.84 \times 10^{-3}$

Sirius ③: $287 \times 10^{-9} \times 9910 = 2.844 \times 10^{-3}$ $\approx 2.84 \times 10^{-3}$

all 3 values are approximately equal to each other, so it ~~they~~ can be said that they are equal to a constant which is close to 2.898×10^{-3} mK, so Wien's law is confirmed by this data.

ResultsPlus
Examiner Comments

This response scored all 3 marks. The constant has been calculated for all 3 stars and they have made a valid conclusion.

(c) At the end of the 19th century, Wien investigated the radiation emitted by hot objects and formulated a law.

The table shows data for some stars.

Star	λ_{max} / nm	T / K
Bellatrix	132	21 500
Rigel	245	11 600
Sirius	287	9910

Deduce whether Wien's law is confirmed by this data.

(3)

132nm = 1.32×10^{-7} m

$1.32 \times 10^{-7} \times 21500 = 2.838 \times 10^{-3}$ wiens law is

245nm = 2.45×10^{-7} m supported by

$2.45 \times 10^{-7} \times 11600 = 2.842 \times 10^{-3}$ the data set.

287nm = 2.87×10^{-7} m

$2.87 \times 10^{-7} \times 9910 = 2.84 \times 10^{-3}$

ResultsPlus
Examiner Comments

This response scored marking point 1 and 2 for correctly calculating the constant for all 3 stars. Marking point 3 was not awarded as the candidate has made no comparison between the constants or compared them to the Wein's law constant.

(c) At the end of the 19th century, Wien investigated the radiation emitted by hot objects and formulated a law.

The table shows data for some stars.

Star	λ_{max} / nm	T / K
Bellatrix	132	21 500
Rigel	245	11 600
Sirius	287	9910

Deduce whether Wien's law is confirmed by this data.

(3)

λ_{max} = constant / T

$132 \times 10^{-9} \times 21500 = 2.838 \times 10^{-3}$

245×10^{-9} ~~x~~ $\times$ 11600 = 2.842

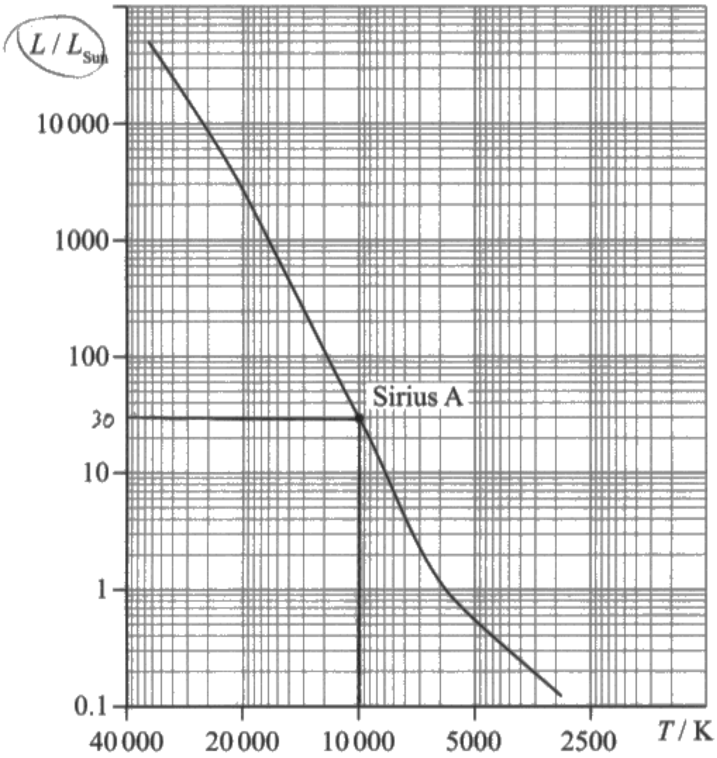
ResultsPlus
Examiner Comments

This response scored marking point 1 only, as the candidate has not calculated the constant for all 3 stars.

Question 21(d)

In this question candidates were asked to deduce whether or not the radius of Sirius was twice the radius of the Sun. The question was generally well answered and a significant amount of responses scored all 5 marks. When this wasn't the case, it was often due to misinterpretation of the logarithmic scale on the graph. Other errors included not being awarded MP1 for not raising temperature to the power of 4, or forgetting to square the radius of the Sun. Occasionally, MP5 was not scored as the candidate had not provided a mathematical comparison or a conclusion.

(d) The Hertzsprung–Russell diagram below shows part of the main sequence of stars.
The star Sirius A is marked on the diagram.



On a website it states that the radius of Sirius A is twice the radius of the Sun.

Deduce whether this statement is correct.

radius of the Sun = 6.96×10^{8} m
surface temperature of the Sun = 5800 K

(5)

$L_{Sun} = 4\pi r^2 \sigma T^4$

$L_{Sun} = 4\pi(6.96\times10^{8})^2 \times 5.67\times10^{-8} \times (5800)^4 = 3.91\times10^{26}$ W

$L_{SiriusA} = 30 L_{Sun} = 30 \times 3.91\times10^{26} = 1.17\times10^{28}$ W

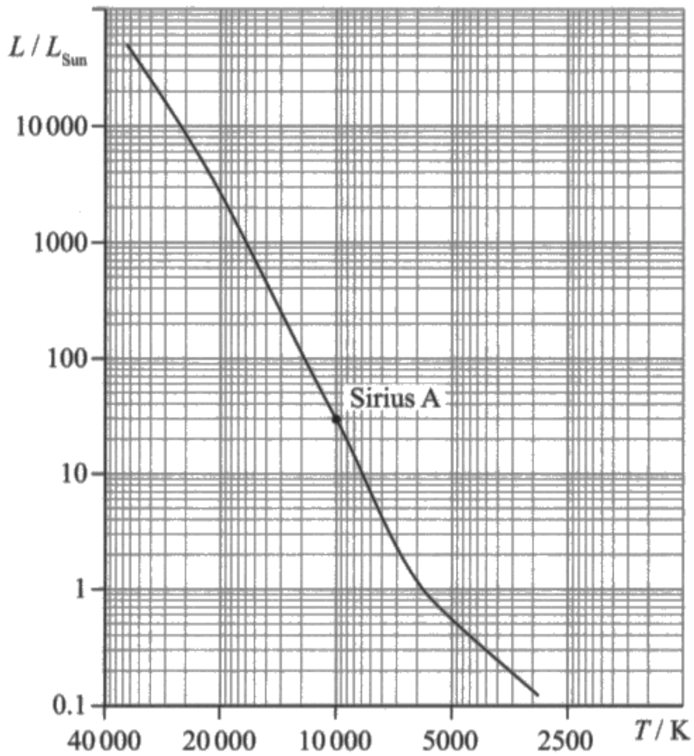
$L_{SiriusA} = 4\pi r^2 \sigma T^4 \Rightarrow r = \sqrt{\frac{L}{4\pi\sigma T^4}} = \sqrt{\frac{1.17\times10^{28}}{4\pi \times 5.67\times10^{-8} \times 10{,}000^4}} = 1.28\times10^{9}$ m

$2r_{Sun} = 2\times6.96\times10^{8} = 1.39\times10^{9}$ m $\approx 1.28\times10^{9}$ m $\therefore$ the Statement is correct.

ResultsPlus Examiner Comments

This response scores all 5 marks. MP1 is awarded for correctly calculating the luminosity of the Sun. The candidate has correctly identified the relevant information from the graph and used this to correctly determine the radius of Sirius. They have also provided a mathematical comparison and a correct conclusion.

(d) The Hertzsprung–Russell diagram below shows part of the main sequence of stars. The star Sirius A is marked on the diagram.



r_0 = radius sun
r_S = Radius sirius A

On a website it states that the radius of Sirius A is twice the radius of the Sun.

Deduce whether this statement is correct.

radius of the Sun = 6.96×10^8 m
surface temperature of the Sun = 5800 K

(5)

$L/L_{sun} = 20$

$T = 10000$ = Surface T of Sirius A

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

$20 L_0 = 4\pi r^2 \sigma T^4$

$r = \sqrt{\dfrac{20 L_0}{4\pi \sigma T^4}} = \sqrt{\dfrac{20(3.9\times10^{26})}{4\pi(5.67\times10^{-8})(10000)^4}}$

$r_s = 1.05 \times 10^9$ m

L of Sun $= 4\pi(6.96\times10^8)^2 \times (5.67\times10^{-8})(5800)^4$

$L_0 = 3.9 \times 10^{26}$

$L_s = 20 L_0$

r_0

$6.96\times10^8 \times 2 = 1.39\times10^9$

$r_s < 2r_{sun}$

Hence website is incorrect.

(Total for Question 21 = 13 marks)

ResultsPlus
Examiner Comments

This response was not awarded marking point 2, as the candidate has misinterpreted the scale on the graph and determined the luminosity of Sirius to be 20 times that of the Sun. This means that marking point 4 could also not be awarded. This scored marking points 1, 3 and 5 for correctly calculating the luminosity of the Sun, using the data from the graph correctly, and providing a comparison and conclusion.

Paper Summary

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

- Candidates should use a ruler when drawing ray diagrams to ensure accuracy and clarity.
- In calculation questions, all values should be clearly substituted into the relevant equations, with full working shown.
- Where the command word is “deduce”, candidates should provide a clear conclusion supported by a mathematical comparison or reasoning.
- Units must always be included in numerical answers, where appropriate.
- Overall, careful attention to detail, structured working and clear reasoning will improve the quality and clarity of responses.

Grade boundaries

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