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# Examiners' Report
# June 2025

## Int Advanced Level Physics WPH15 01

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# Introduction

The assessment structure of WPH15 mirrors that of WPH14. It consists of 10 multiple choice questions, a number of short answer questions and some longer, less structured questions.

As it is an A2 assessment unit, synoptic elements are incorporated into this paper. There is overlap with circular motion and exponential variation in Unit 4, but also overlap with some of the AS content from Units 1 and 2.

The paper includes the use of specific command words as detailed in the specification, Appendix 9: Taxonomy. It is recommended that centres ensure that their students understand what is required when responding to such questions. In this paper where the command word was 'deduced', 'evaluated', or 'assessed', the final mark could sometimes not be awarded on otherwise good responses because a final appropriate comment was missing.

Candidates should be encouraged to read questions carefully to ensure that their responses take into account all the relevant information. Section B questions are set in context. Candidates should be aware that the context of the physics in which the question is set and all supplementary information provided are required for a complete response that could gain full marks.

Sometimes candidates start their response by repeating the question.

This may mean that they struggle to get all of the relevant points in the space provided.

Candidates should be encouraged to consider the number of marks available for a question, and to use this to inform their response. If candidates either need more space or want to replace an answer, they should indicate clearly where that response is to be found.

Candidates should be encouraged to work with mark schemes in preparation for their exam. However, it is important that they understand that mark schemes do not provide model answers to questions. Mark schemes are written for examiners, and so sometimes refer to what examiners expect to see rather than giving a complete answer.

Multiple Choice Questions

In general candidates' performance in this section of the paper was similar to candidates' performance in previous series. The mean mark for this section was 7 out of 10, with only Q3 and Q6 having a facility less than 0.6

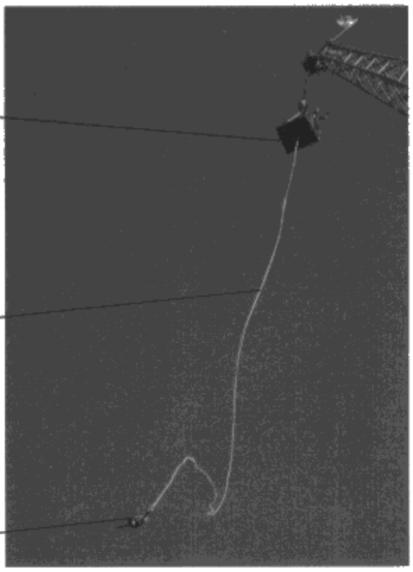
Q3 required a comparison of how binding energy per nucleon changes for fission and fusion.

Q6 was set in a practical context, and required candidates to combine knowledge of the inverse square law with background count rate.

# Question 11

The majority of candidates attempted this question very well and demonstrated a good understanding of the concept being tested. Most responses showed the correct application of the relevant formula. However, in some cases, candidates failed to add the two masses where required, which led to incorrect final answers. Some responses missed out on MP3 due to calculation errors in determining the spring constant. A few candidates selected the pendulum equation, and occasionally the use of the Boltzmann constant or the Coulomb's law constant was seen substituted for $k$.

**11** The photograph shows a woman making a bungee jump. The woman was attached to a platform high above the ground by an elastic rope.




(Source: © Pearson Asset Library)

After reaching the lowest point of the bungee jump, the woman oscillated with simple harmonic motion of period 1.50 s.

The woman returned to the platform to repeat the bungee jump. She was fastened to a second person. The same elastic rope was used for the bungee jump.

After reaching the lowest point of the bungee jump, the two people oscillated with simple harmonic motion.

Calculate the period of oscillation of the two people.

mass of woman = 67 kg
mass of second person = 72 kg

$T = 2\pi\sqrt{\frac{m}{k}} \Rightarrow T_1 = 1.50 = 2\pi\sqrt{\frac{67}{k}}$

$T_2 = 2\pi\sqrt{\frac{67+72}{k}} \Rightarrow \frac{T_2}{T_1} = \sqrt{\frac{67+72}{67}} = 1.44$

$\Rightarrow T_2 = 1.44 \times 1.50 = 2.16s$

Period of oscillation = 2.16s

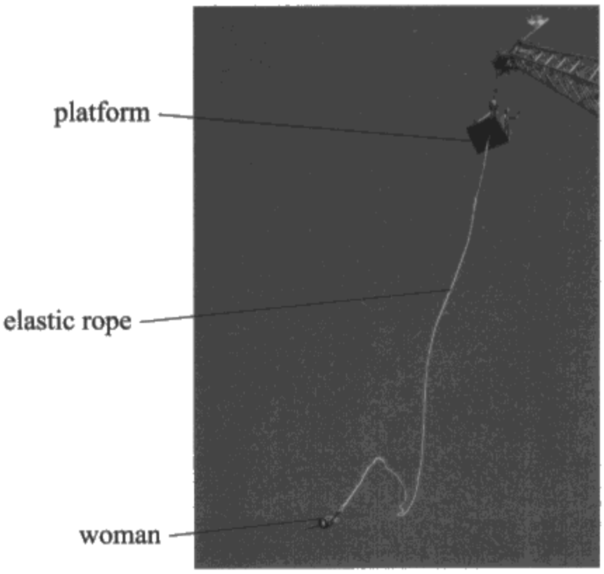
**ResultsPlus**
**Examiner Comments**

This response follows the method used by most candidates. After using the time period equation to calculate a value for k, the time period equation is used again to calculate the new period. The final answer is correct with units, and so all 3 marks are scored. Note that, from the handwriting, the unit (s) could be a number five (5), although this was disregarded here.

**ResultsPlus**
**Examiner Tip**

Write numerical values and units clearly.

**11** The photograph shows a woman making a bungee jump. The woman was attached to a platform high above the ground by an elastic rope.




(Source: © Pearson Asset Library)

After reaching the lowest point of the bungee jump, the woman oscillated with simple harmonic motion of period 1.50 s.

The woman returned to the platform to repeat the bungee jump. She was fastened to a second person. The same elastic rope was used for the bungee jump.

After reaching the lowest point of the bungee jump, the two people oscillated with simple harmonic motion.

Calculate the period of oscillation of the two people.

mass of woman = 67 kg
mass of second person = 72 kg

$T = 2\pi\sqrt{\frac{m}{k}}$

$T \propto \sqrt{m}$ k is same

$m_1 = 67\,kg$

$m_2 = 67+72 = 139\,kg$

$T_1 = 1.5\,s$

$\frac{T_2}{T_1} = \sqrt{\frac{m_2}{m_1}}$

$T_2 = T_1\sqrt{\frac{m_2}{m_1}}$

$T_2 = 1.5\sqrt{\frac{139}{67}}$

$T_2 = 1.5 \times 1.44$

$= 2.16\,s$

Period of oscillation = 2.16 s

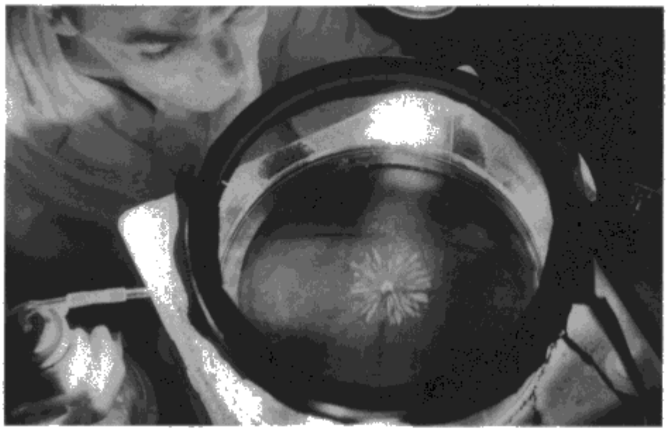
**ResultsPlus**
**Examiner Comments**

This response uses the less frequently seen ratio method. The final answer is correct and units are included, so this scored all 3 marks.

# Question 12

This was a challenging question for many candidates. The mean mark for this item was 2, and only a quarter of responses scored full marks. Although a large number of candidates demonstrated a correct understanding of the relationship between the thickness of the material, ionising ability, and the shape of the particle tracks, many framed their answers as a comparison between alpha and beta particles, rather than directly addressing the question. Some candidates missed out the 'criticise' part of the question, writing all the statements correctly but not saying where the student in the question was wrong. Others confused the cause and effect and there was a general lack of clarity about the use of ambiguous words like 'bigger'/'larger'. The best responses separated the two effects into two distinct and separate causes, making their response 'clarity'.

**12** The photograph shows a student observing the tracks of alpha particles and beta particles in a cloud chamber.



(Source: © NASA Archive/Alamy Stock Photo)

The particles ionise the air as they pass through the cloud chamber. Liquid droplets form around the ions and the droplets form visible tracks.

The alpha particle tracks are thick and straight. The beta particle tracks are thin and twisted.

The student gives the following explanation for the appearance of the tracks.

"*The alpha particle tracks are thick because the alpha particles are massive particles. The tracks are straight because the alpha particles are highly ionising.*

*The beta particles cause a similar amount of ionisation as the alpha particles. The beta particle tracks are thin and twisted because beta particles are much less massive than alpha particles.*"

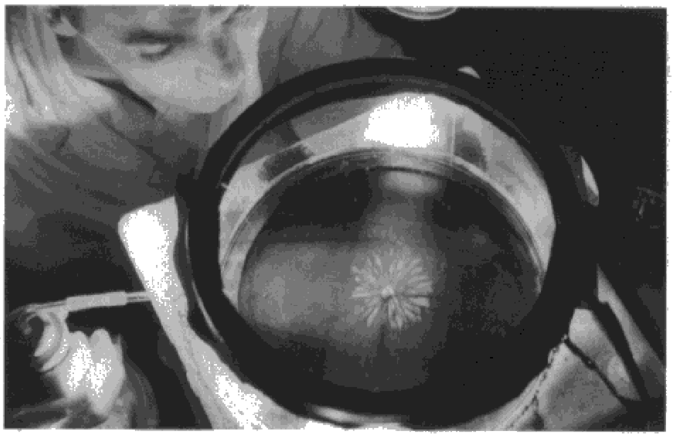
Criticise the student's explanation.

- The statement that alpha particles are thick because they are massive is incorrect, they are thick because of significant ionization which alpha particles produce. They are correct to say that alpha particles are highly ionizing.
- They are incorrect to say that $\beta$ particles are similarly ionising, in fact, $\beta$ particles have relatively lower ionizing ~~of~~ ability than alpha particles. They are correct to say the $\beta$ tracks are thin and twisted because $\beta$ particles have lower mass, therefore momentum, requiring less force to redirect.

**ResultsPlus**
**Examiner Comments**

This response clearly makes the link between cause and effect for the appearance of the tracks. There is also a critique of the statement included, so all 4 marks were scored.

**12** The photograph shows a student observing the tracks of alpha particles and beta particles in a cloud chamber.



(Source: © NASA Archive/Alamy Stock Photo)

The particles ionise the air as they pass through the cloud chamber. Liquid droplets form around the ions and the droplets form visible tracks.

The alpha particle tracks are thick and straight. The beta particle tracks are thin and twisted.

The student gives the following explanation for the appearance of the tracks.

"*The alpha particle tracks are thick because the alpha particles are massive particles. The tracks are straight because the alpha particles are highly ionising.*

*The beta particles cause a similar amount of ionisation as the alpha particles. The beta particle tracks are thin and twisted because beta particles are much less massive than alpha particles.*"

Criticise the student's explanation.

alpha particle tracks are thick because alpha particles are highly ionising particles. the tracks are straight because alpha particles are massive particles. The beta particles cause a ~~similar~~ ~~that~~ lower (weaker) ionisation than alpha, so tracks are thinner than alpha track. the beta particles ~~are~~ have no mass -β so it is twisted.

**ResultsPlus**
**Examiner Comments**

This response identifies the key features of the tracks formed by each particle and correctly gives reasons for the appearance of the tracks. However, there is no attempt to comment directly on the statement made in the question, and so this response scores a maximum 3 marks for the discussion of the tracks, but not MP1.

**ResultsPlus**
**Examiner Tip**

When the command word is 'criticise', remember to comment on the information provided in the question.

## Question 13(a)

Approximately one third of the responses seen gained full marks for this question. A common mistake was to add the two distances when calculating the gravitational potential. Many candidates also failed to multiply the mass by the gravitational potential. A few candidates tried to calculate a value for *g* and then use the GPE equation. As there is a large variation in *g* for the situation given in the question, no credit was given for this method.

**13** A satellite of mass $6.50 \times 10^3$ kg is initially at the surface of the Earth. The satellite is launched into a circular orbit of radius $4.22 \times 10^7$ m.

(a) Calculate the change in gravitational potential energy of the satellite.

DC

mass of Earth = $5.98 \times 10^{24}$ kg
radius of Earth = $6.37 \times 10^6$ m

↳ KE ?

**(3)**

$$GPE = -\frac{GMm}{r}$$

$$\Delta = \left(-\frac{6.67\times10^{-11} \times 5.98\times10^{24} \times 6.5\times10^{3}}{4.22\times10^{7}}\right) - \left(\frac{-6.67\times10^{-11}\times5.98\times10^{24} \times 6.5\times10^{3}}{6.37\times10^{6}}\right)$$

$= 3.45569.. \times 10^{11}$

$= 3.46 \times 10^{11}$ J

Change in gravitational potential energy = $3.46 \times 10^{11}$ J

**ResultsPlus**
**Examiner Comments**

This response scores all 3 marks for a correct answer with units.

**13** A satellite of mass $6.50 \times 10^3$ kg is initially at the surface of the Earth. The satellite is launched into a circular orbit of radius $4.22 \times 10^7$ m.

(a) Calculate the change in gravitational potential energy of the satellite.

mass of Earth = $5.98 \times 10^{24}$ kg
radius of Earth = $6.37 \times 10^6$ m

**(3)**

$\Delta V = -\frac{GM}{r_2} - \left(-\frac{GM}{r_1}\right)$

$= GM\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$ ~~$= 6.67\times10^{-11} \times 5.98$~~

$= 6.67\times10^{-11} \times \cancel{5.98\times10^{24}}\ 6.5\times10^{3} \times \left(\frac{1}{6.37\times10^6} - \frac{1}{6.37\times10^6 + 4.22\times10^7}\right)$

~~$\Delta E = \Delta V \times M =$~~ $= 5.913\times10^{-14}$ $N\,m\,kg^{-1}$

$\Delta E = \Delta V \times M = 5.913\times10^{-14} \times 5.98\times10^{24} = 3.54\times10^{11}$ J

Change in gravitational potential energy = $3.54\times10^{11}$ J

**ResultsPlus**
**Examiner Comments**

This response illustrates a common error seen. The radius of the Earth has been added to the orbit radius. This leads to an incorrect answer which is close to the correct answer. The response gains MP1 and MP2, but not MP3.

**ResultsPlus**
**Examiner Tip**

Read the question carefully to establish what values given in the question represent.

**13** A satellite of mass $6.50 \times 10^3$ kg is initially at the surface of the Earth. The satellite is launched into a circular orbit of radius $4.22 \times 10^7$ m.

(a) Calculate the change in gravitational potential energy of the satellite.

mass of Earth $= 5.98 \times 10^{24}$ kg
radius of Earth $= 6.37 \times 10^6$ m

**(3)**

$\Delta E_p = mgh = \frac{-Gm}{r^2}$ $\qquad$ $E_p = \frac{-9.81 \times 6.50 \times 10^3}{4.22 \times 10^7}$

$E_{p\ \text{earth}} = \frac{-9.81 \times 5.98 \times 10^{24}}{637 \times 10^6}$ $\qquad$ $= -1.511 \times 10^{-3}$

$= -9.2094 \times 10^{18}$

$= 9.2 \times 10^{18}$

Change in gravitational potential energy = $9.2 \times 10^{18}$ J

**ResultsPlus**
**Examiner Comments**

This response confuses G and g, so MP1 is not awarded. There is no attempt to multiply a potential by the mass of the satellite and so MP2 is not given. The final answer is incorrect, so not MP3.

# Question 13(b)

Just less than one third of the responses seen gained full marks.

Most responses were working towards comparing values for the orbital time T, but some responses chose to compare values for the angular velocity ω. MP4 was only awarded for a full conclusion (including a comparison of values), so some missed out on this mark.

Many well expressed solutions were seen, including various approaches to comparing values.

In some responses the Kepler equation was used.

It is worth noting that there is no credit for 'use of' this equation, although correct answers obtained by using this equation earned full credit.

(b) The satellite is in orbit above the equator.

Deduce whether the satellite would appear to be stationary above the surface of the Earth.

period of rotation of Earth about its axis = $8.64 \times 10^4$ s

**(4)**

Force on satellite = $\frac{Gm_1m_2}{r^2} = m_2\omega^2 r$ $\quad \omega = \sqrt{\frac{Gm}{r^3}}$

$\omega = \sqrt{\frac{6.67\times10^{-11} \times 5.98\times10^{24}}{(4.22\times10^7)^3}} = 7.29\times10^{-5}$ rad $s^{-1}$

$T = \frac{2\pi}{\omega} = \frac{2\pi}{7.29\times10^{-5}} = 86200\,s = 8.62\times10^4$ $\quad \cancel{86}\ \frac{8.64\times10^4 - 8.62\times10^4}{8.64\times10^4} \times 100 = 0.23\%$

Period of satellite's orbit is almost equal to period of Earth's rotation so the satellite would appear to be stationary.

## ResultsPlus Examiner Comments

This response calculates a correct value for the period of the satellite. A comparison is made with the period of rotation of the Earth (the percentage difference between the two values is calculated) and a consistent conclusion made. Hence the response scores full marks.

## ResultsPlus Examiner Tip

Be sure to write a full conclusion for 'assess'/'deduce'/'evaluate' questions.

(b) The satellite is in orbit above the equator.

Deduce whether the satellite would appear to be stationary above the surface of the Earth.

period of rotation of Earth about its axis = $8.64 \times 10^4$ s

**(4)**

~~$mg = \frac{GMm}{r^2}$~~ ~~$F = mr\omega^2$~~ $\omega = \frac{2\pi}{T} = \frac{2\pi}{8.64\times10^4}$ $\frac{GMm}{r^2} = mr\omega^2$

~~$= 6.5\times10^3 \times 6.37\times10^6$~~ $GM = r^3\omega^2$

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

~~$= \frac{6.67\times10^{-11} \times 5.98\times10^{24} \times 6.50\times10^3}{(6.37\times10^6)^2}$~~ $= 6.389\times10^4$ N $r^3 = \frac{6.67\times10^{-11} \times 5.98\times10^{24}}{\left(\frac{2\pi}{8.64\times10^4}\right)^2}$

~~$F = mr\omega^2 = 6.5\times10^3 \times 6.37\times10^6 \times \left(\frac{2\pi}{8.64\times10^4}\right)^2 =$~~ $r = 4.23\times10^7$ m

$4.23\times10^7 \text{ m} > 6.37\times10^6 \text{ m}$

So the satellite would appear to be stationary above the surface of earth.

**(Total for Question 13 = 7 marks)**

**ResultsPlus**
**Examiner Comments**

This response attempts an unusual method of solution. The gravitational and circular motion equations are used to calculate a correct value for the radius of orbit of a satellite that would appear to be stationary above the surface of the Earth. Hence MP1, MP2 and MP3 can all be awarded. The orbital radius is then compared with the radius of the Earth, which is an incorrect comparison. Hence MP4 is not awarded. Note that the conclusion following the comparison is not consistent with the two values compared being very different, hence MP4 would not have been awarded even if the radius of orbit had been compared with a sensible distance.

## Question 14(a)

Most candidates could relate parallax angle with distance for MP1, but MP2 was less common to score. Common responses that did not gain credit stated that the angle was too small or difficult to measure, instead of referring to the resolution of the instrument. More successful responses referred to accuracy or uncertainty in the measurement.

**14** Astronomers use a variety of methods to determine the distances to astronomical objects.

(a) Explain why trigonometric parallax can only be used to determine the distance to objects that are relatively close to the Earth.

**(2)**

Trigonometric ~~parra~~ parallax is not suitable for objects far from earth because it would yield a great percentage uncertainty since the change in angular position ~~~~ will be extremely small. Hence it is only suitable to close objects where the change in angular position ~~~~ is large enough for a valid calculation

ResultsPlus
Examiner Comments

This response refers to the change in angular position rather than the parallax angle, but that is fine and MP1 is awarded. The reference to a great percentage uncertainty for object far from the Earth is good enough for MP2, so the response scores both marks.

**14** Astronomers use a variety of methods to determine the distances to astronomical objects.

(a) Explain why trigonometric parallax can only be used to determine the distance to objects that are relatively close to the Earth.

**(2)**

Because the further away the object is the smaller its parallax angle hence it becomes more difficult to measure it, therefore its uncertainty increases, and ~~no~~ hence $\tan\theta = \frac{AU}{d}$ is much more difficult to be used, since $\theta$ will be difficult to be measured.

ResultsPlus
Examiner Comments

MP1 is seen in the first two lines of the response. In lines 3 and 5 the reference to "more difficult to measure" would not be sufficient for MP2. However, the reference to uncertainty increasing is just about enough for MP2.

**14** Astronomers use a variety of methods to determine the distances to astronomical objects.

(a) Explain why trigonometric parallax can only be used to determine the distance to objects that are relatively close to the Earth.

**(2)**

• It is hard to measure the angle for ~~stars~~ ~~that~~ objects at a high distance from the earth in space

• There ~~[illegible]~~ are too many background stars which interfere with measuring the angle.

**ResultsPlus**
**Examiner Comments**

This response scores zero. There is no reference to the parallax angle being small for distant stars, so MP1 is not given. "Hard to measure" is insufficient for MP2 and the reference to background stars interfering with the measurement of the angle is not enough either.

# Question 14(b)i

Almost three quarters of responses gained the mark for this item. Some responses gave unnecessary detail relating to the way in which the luminosity of the standard candle was known. Some identified 'standard candle' as the method, rather than stating what a 'standard candle' is. A wide range of astronomical objects are used as standard candles, but references to planets and satellites were not accepted.

(b) For objects that are not close to the Earth, the method of standard candles is used.

(i) State what is meant by a standard candle.

(1)

Stellar object with known luminosity.

**ResultsPlus**
**Examiner Comments**

This succinct response scores the mark.

(b) For objects that are not close to the Earth, the method of standard candles is used.

(i) State what is meant by a standard candle.

**(1)**

- It's a method of ~~the~~ estimating the distance of stars and galaxies by ~~average~~ using candles.

**ResultsPlus**
**Examiner Comments**

In each series a small number of responses describe "standard candle" as a method of determining the distances to astronomical objects. This does not state what a standard candle is. Note that the wording of the question refers to the "method of standard candles" but requires candidates to state "what is meant by a standard candle". This response scores zero.

# Question 14(b)ii

Only one third of the responses seen gained full marks for this question. Common errors see included omitting to state that a standard candle had to be located in the cluster, or to give the intensity equation without stating what the symbols represented.

(ii) Describe how the method of standard candles is used to determine the distance to a distant star cluster.

(3)

· Identify a standard candle in the star cluster · Luminosity is known

· Measure the intensity of radiation ~~of the standar~~

· Use $d = \sqrt{\dfrac{L}{4\pi I}}$ where $L$ = luminosity

$I$ = Intensity of radiation

to get the distance d.

**ResultsPlus**
**Examiner Comments**

This response scores full marks. The luminosity equation is quoted, but symbols are defined.

This response scores all 3 marks. It is clear that a standard candle is located in the cluster for MP1 and that the intensity of this standard candle is measured for MP2. The equation quoted does not have symbols defined, but there is also a reference to the inverse square law and so MP3 is awarded.

Note that the use of technical vocabulary is important in this question. The intensity must be measured, and not just observed, or found, or calculated.

(ii) Describe how the method of standard candles is used to determine the distance to a distant star cluster.

**(3)**

→ A standard candle eg. cepheid variable / type II supernova is located in a distant star cluster ~~of~~ (or in the chosen cluster) or galaxy near (or in) the chosen star cluster. The luminosity of the standard candle is known. The intensity of radiation from the standard candle is measured, and the inverse square relation ($I = \frac{L}{4\pi d^2}$) is used to calculate the distance to this star cluster.

**ResultsPlus**
**Examiner Comments**

Use correct technical vocabularly in a response to a descriptive question.

(ii) Describe how the method of standard candles is used to determine the distance to a distant star cluster.

$I = \frac{L}{4\pi d^2}$ **(3)**

~~A star of ~~two~~ known ~~luminosity~~ is chosen~~

~~A star is chosen and ~~earth~~~~

The intensity of light from distant star on earth is measured. ~~So~~ The standard candles intensity is already known. $I = \frac{L}{4\pi d^2}$ is used to find out d.

ResultsPlus
Examiner Comments

This response scores 1 mark. There is no reference to locating a standard candle, so not MP1. The sentences that refer to a star of known luminosity being chosen comes close to this, but this is crossed out anyway. The first two lines of the response gain MP2, but the equation isn't enough for MP3 as symbols are not defined.

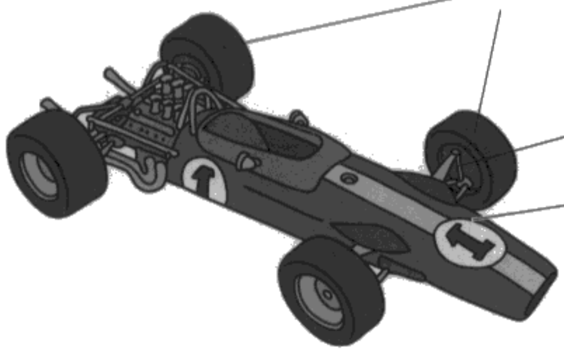
ResultsPlus
Examiner Tip

If you use an equation as part of an explanation, always state what the symbols in the equation represent.

# Question 15(a)

This question has been asked many times in various contexts, but it still elicits a mixed response. Candidates sometimes referred to displacement but not where the displacement is measured from. Similarly, reference is sometimes made to acceleration (or resultant force) toward equilibrium, and not toward the equilibrium position. For this reason it was common for responses to score just 1 mark. Candidates need to remember that the displacement must be from the equilibrium position, and that the acceleration (or resultant force) is always towards the equilibrium position.

**15** The body of a racing car is connected to the wheels of the racing car by a suspension system, as shown.




(Source: © Jana Vostal / Alamy Stock Vector)

When the body of the racing car is displaced vertically from its equilibrium position, the suspension system causes the car to oscillate with simple harmonic motion.

(a) State the conditions for an object to oscillate with simple harmonic motion.

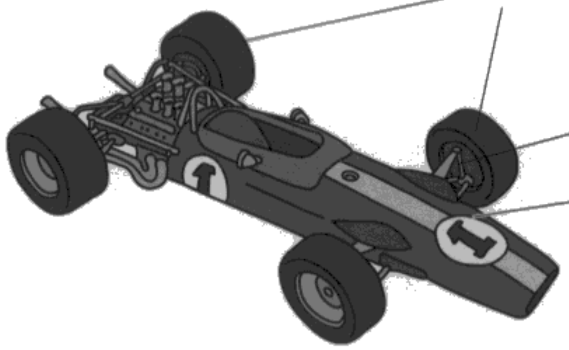
**(2)**

The resultant force should be directly proportional to the displacement of object from equilibrium position. The resultant force should always be acting towards equilibrium position

**ResultsPlus**
**Examiner Comments**

This response has all the key elements of the conditions for simple harmonic motion and scores both marks.

**15** The body of a racing car is connected to the wheels of the racing car by a suspension system, as shown.

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When the body of the racing car is displaced vertically from its equilibrium position, the suspension system causes the car to oscillate with simple harmonic motion.

(a) State the conditions for an object to oscillate with simple harmonic motion.

**(2)**

the acceleration must be proportional to displacement and always acting towards the equilibrium position.

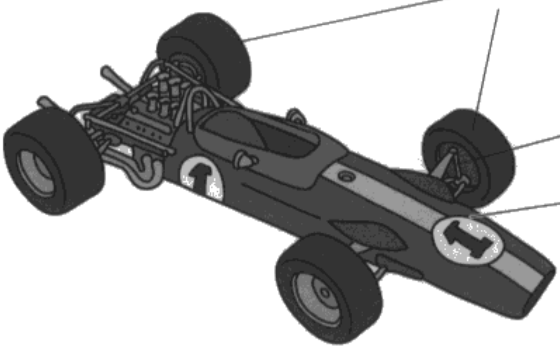
**ResultsPlus**
**Examiner Comments**

This response does not say enough for MP1, as the displacement must be from the equilibrium position. However, there is enough for MP2 and so the response scores 1 mark.

**ResultsPlus**
**Examiner Tip**

Learn standard definitions in preparation for the examination.

**15** The body of a racing car is connected to the wheels of the racing car by a suspension system, as shown.




(Source: © Jana Vostal / Alamy Stock Vector)

When the body of the racing car is displaced vertically from its equilibrium position, the suspension system causes the car to oscillate with simple harmonic motion.

(a) State the conditions for an object to oscillate with simple harmonic motion.

**(2)**

acceleration is proportional to displacement from equilibrium position. acceleration acts in opposite direction to displacement.

This response gives the conditions in terms of acceleration rather than force. Note that "acceleration acts in opposite direction to displacement" is a valid alternative to "acceleration is always acting towards the equilibrium position". The response scores both marks.

## Question 15(b)

Candidates performed well on this question with almost one third of the responses seen scoring full marks. Most candidates read two values from the graph and used s.h.m. equations to calculate the velocity. A common error seen with this method was not realising that sin $\omega t$ = 1 at maximum amplitude. An alternative approach involved drawing a tangent to the graph at a time at which y = 0. A small range was allowed for answers derived via this method, but some candidates still obtained a velocity outside of this range. In either method there was the possibility of getting units mixed up. Once again, fractions were seen in candidate's final answers.

Determine the maximum velocity of the car body.

**(4)**

$T = 0.6 - 0.2 = 0.4s$ .

$T = \frac{2\pi}{\omega}$ $\omega = \frac{2\pi}{0.4} = 5\pi$

$v = A\omega$

$= 0.03 \times 5\pi \times 1$

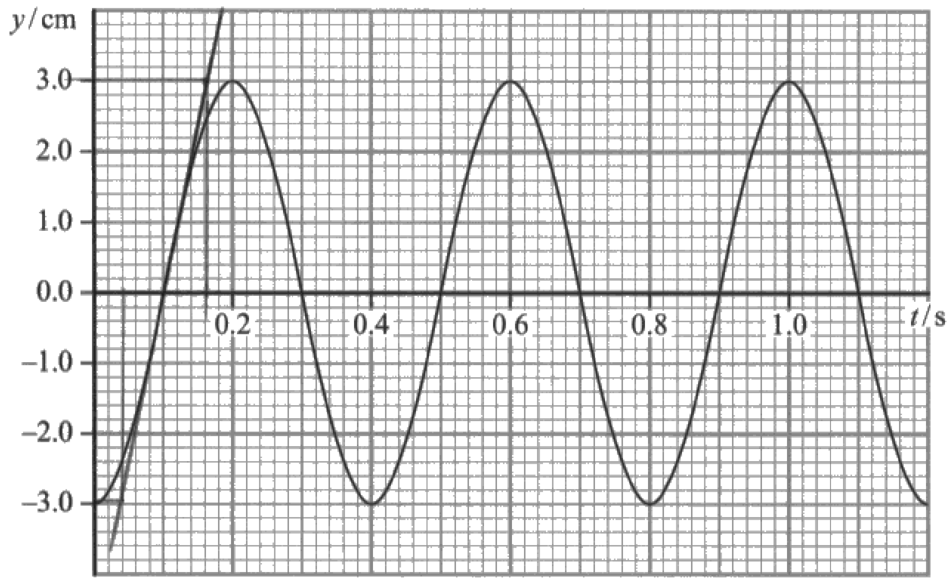
$= 0.471$ m/s

Maximum velocity of car body = 0.471 m/s.

## ResultsPlus
**Examiner Comments**

This response has correct values read from the graph and appropriate equations used to obtain the correct answer. The units are required here, and m/s is acceptable. The response scores 4 marks.

(b) The graph shows how the vertical displacement $y$ of the car body varies with time $t$.




~~0·1~~
~~0·08~~
(0–2,*

Determine the maximum velocity of the car body. 2 1.

(4)

$V_{max}$ = gradient of graph. $(0{\cdot}16, 3\times10^{-2})$ & $(0{\cdot}04, -3\times10^{-2})$

$$V_{max} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{3\times10^{-2} - (-3\times10^{-2})}{0{\cdot}16 - 0{\cdot}04}$$

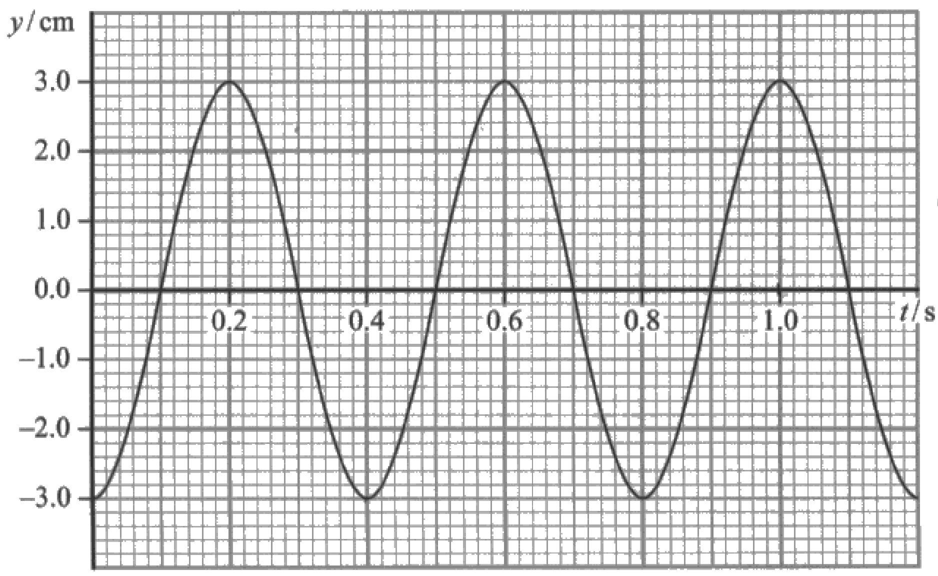
$V_{max}$ = 0·5 m/s

Maximum velocity of car body = 0·5 m/s

## ResultsPlus Examiner Comments

This response draws a tangent to the curve at an appropriate point to obtain a correct answer. Again, m/s for units of velocity is acceptable. The response scores full marks.

(b) The graph shows how the vertical displacement $y$ of the car body varies with time $t$.




$A = 3$

$\omega = 2\pi f$

$= \frac{2\pi}{T}$

$T = 0.4$

Determine the maximum velocity of the car body.

**(4)**

$v = \cancel{A \sin \omega t}$ $A\omega \sin \omega t$

$\omega = \frac{2\pi}{T} = \frac{2\pi}{0.4}$

$= 5\pi \text{ rad s}^{-1}$

$A = 3 \text{ cm}$

$v = 3 \times 5\pi \sin(5\pi \times 0.2)$

$= 2.58 \text{ cm s}^{-1}$

Maximum velocity of car body = $2.58 \text{ cm s}^{-1}$

**Examiner Comments**

This response includes correct readings from the graph and these values are used to calculate the angular frequency. Hence MP1 and MP2 are awarded. The final answer is incorrect, as sin(wt) hasn't been put equal to 1. Hence there is no further credit, and the response scores 2 marks.

**Examiner Tip**

When reading values from a graph, use annotations on the graph to help you.

# Question 15(c)

About half the responses seen gained MP1.

When resistive forces were mentioned, candidates often did not specify how this related to energy, so did not go on to talk about work done. In some cases candidates misunderstood what work was done on, saying work was done on the car body rather than by it.

When work is done on a body, this means energy is transferred to it; when work is done by a body, energy is transferred away from it.

Some responses tried to link the question with resonance, but this did not gain credit.

(c) Explain how damping causes the amplitude of oscillation of the car body to decrease.

(2)

There will be energy transfer to the surroundings.

~~The~~ Work is done against the resistive force.

So the amplitude will decrease.

**ResultsPlus Examiner Comments**

This responses scores MP1 and MP2 as given in the mark scheme, so the response scores full marks.

**ResultsPlus Examiner Tip**

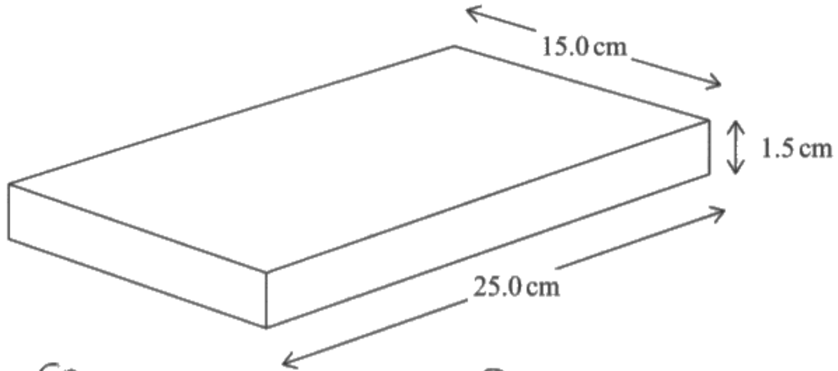
When referring to work done, be clear if it is 'work done on' or 'work done by'.

## Question 16(a)

Two thirds of the responses seen gained full marks for this question. In responses that did not score full marks errors such as not converting lengths into metres, or confusing the specific heat capacity and latent heat in the formulas. Less common was to substitute only one temperature value (converted to Kelvin). Some responses did not score MP5 because the energies were subtracted instead of added.

**16** A food delivery company uses ice packs to keep food cold during delivery. Each ice pack consists of a block of ice in a waterproof bag.

Each block of ice is initially rectangular, as shown.




Energy to reduce temp + freeze it

(a) Water at 0.0 °C is frozen to form the block of ice. The block is cooled to a temperature of –7.5 °C. The block is then sealed in the waterproof bag.

Determine the energy transferred to form the ice block and reduce its temperature to –7.5 °C.

density of ice = 920 kg m$^{-3}$
specific latent heat of fusion of water = $3.4 \times 10^5$ J kg$^{-1}$
specific heat capacity of ice = 2100 J kg$^{-1}$ K$^{-1}$

**(5)**

mass = density x volume

volume = L x W x H
= 15.0cm x 1.5 x 25.0
= 562.5cm$^3$
= $5.625 \times 10^{-4}$ m$^3$

mass = $920 \times 5.625 \times 10^{-4}$
= 0.5175kg

$E = mc\Delta\theta$
= $0.5175 \times 2100 \times (7.5)$
= 8150.625 J

E = fuseit = L$\Delta$m
= $3.4 \times 10^5 \times 0.5175$
= 175950 J

$E_T$ = 8150.625 + 175950
$E_T$ = 184100.625 J
$E_T$ = $1.84 \times 10^5$ J

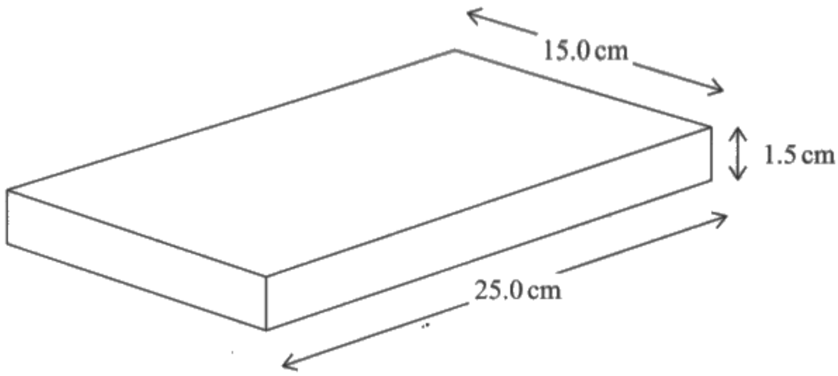
Energy transferred = $1.84 \times 10^5$ J

ResultsPlus
Examiner Comments

This response sets out the solution clearly. A correct answer with units is obtained and so the response scores all 5 marks.

**16** A food delivery company uses ice packs to keep food cold during delivery. Each ice pack consists of a block of ice in a waterproof bag.

Each block of ice is initially rectangular, as shown.




(a) Water at 0.0 °C is frozen to form the block of ice. The block is cooled to a temperature of –7.5 °C. The block is then sealed in the waterproof bag.

Determine the energy transferred to form the ice block and reduce its temperature to –7.5 °C.

density of ice = $920\,kg\,m^{-3}$
specific latent heat of fusion of water = $3.4 \times 10^5\,J\,kg^{-1}$
specific heat capacity of ice = $2100\,J\,kg^{-1}\,K^{-1}$

**(5)**

$V = \frac{25}{100} \times \frac{15}{100} \times \frac{1.5}{100} = 5.63 \times 10^{-4}\,m^3$

$m = 5.63 \times 10^{-4} \times 920 = 0.518\,kg$

$E = 0.518 \times 2100 \times (7.5) + 0.518 \times 3.4 \times 10^5$

$= 1.84 \times 10^5\,J$

Energy transferred = ..............................

ResultsPlus
Examiner Comments

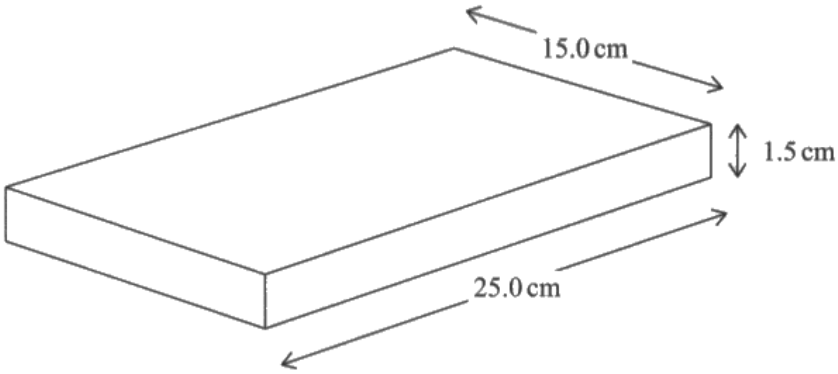
The final answer is correct with units and so this response scores full marks. Note that a number of steps are combined together in this response. This isn't a problem if the final answer is correct, but if an arithmetic error occurs, then it may be that some process marks would not be awarded if clear "use of" equations is not seen.

ResultsPlus
Examiner Tip

In an extended calculation, show all the steps in your working.

**16** A food delivery company uses ice packs to keep food cold during delivery. Each ice pack consists of a block of ice in a waterproof bag.

Each block of ice is initially rectangular, as shown.




(a) Water at 0.0 °C is frozen to form the block of ice. The block is cooled to a temperature of –7.5 °C. The block is then sealed in the waterproof bag.

Determine the energy transferred to form the ice block and reduce its temperature to –7.5 °C.

$\Delta E = L \Delta m$

$\Delta E = mc\Delta\theta$

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

specific latent heat of fusion of water = $3.4 \times 10^5\,J\,kg^{-1}$

specific heat capacity of ice = $2100\,J\,kg^{-1}\,K^{-1}$

**(5)**

To form ice: $\Delta E = L \times \Delta m$

$\rho = \frac{m}{V}$ , $m = \rho V = 920 \times (\cancel{15 \times 1.5 \times 25}\ 0.015 \times 0.0015 \times 0.025)$

$m = 5.175 \times 10^{-4}$ kg

$\Delta E_1 = (3.4 \times 10^5) \times 5.175 \times 10^{-4} = 175.95$

To cool ice: $\Delta E = mc\Delta\theta$

$\Delta E_2 = 5.175 \times 10^{-4} \times 2100 \times (-7.5) = -8.150625$

$\Delta E_{(tot)} = \Delta E_1 + \Delta E_2 = 175.95 - 8.150625$

$\Delta E = 167.799\ J \approx 167.8\ J$

Energy transferred = 167.8 J

ResultsPlus Examiner Comments

All the steps in the calculation are carried out correctly apart from the last step in which energies are combined. This response scores all 4 process marks, but does not gain MP5.

ResultsPlus Examiner Tip

Write an energy balance equation to keep track of energy transfers.

# Question 16(b)

Surprisingly, there were quite a few incorrect responses on this question, giving the item a mean mark of 1. A significant number of candidates forgot the rule that energy transfer is from hot to cold, seeming to think that either the ice was using its own energy to melt, or that energy was given to the surroundings by the ice.

(b) The website of the delivery company includes the following statement.

*If the ice has melted by the time you receive your delivery, this means that energy from the ice has been used to keep the food cold.*

Explain why the statement made by the company is **not** correct.

**(2)**

The energy to melt the ice comes from the surroundings and it $= H L_f, = m \times L_f$, latent heat, It does not come from ice itself. To melt ice energy absorbed is due to latent heat of fusion which comes from surroundings. The energy is not released by ice, Ice acts as ~~a~~ ~~[illegible]~~ a sink, ~~[illegible]~~ not a source, Therefore Company claim was incorrect energy was taken in by ice not given out

**(Total for Question 16 = 7 marks)**

**ResultsPlus**
**Examiner Comments**

This response demonstrates a correct understanding of the energy transfers occurring as the ice melts. It scores 2 marks.

(b) The website of the delivery company includes the following statement.

| |
|---|
| *If the ice has melted by the time you receive your delivery, this means that energy from the ice has been used to keep the food cold.* |

Explain why the statement made by the company is **not** correct.

**(2)**

Because not all the energy is transferred to food but some is dissipated to the surroundings and some energy was used to increase internal energy as when melting the Potential energy increases ~~[illegible]~~ So energy from ice when melting goes to PE not food

**ResultsPlus**
**Examiner Comments**

This response is typical of those candidates who thought that the statement in the question was correct and the ice supplies energy to keep the food cold. The response scored zero.

(b) The website of the delivery company includes the following statement.

> *If the ice has melted by the time you receive your delivery, this means that energy from the ice has been used to keep the food cold.*

Explain why the statement made by the company is **not** correct.

**(2)**

- The temperature of the surrounding is greater than the temperature of the ice block
- Therefore thermal energy is transfered from the surrounding to the ice block ~~and~~ ; this provides the latent heat of melting and the ice melt's
- The statement is incorrect.

ResultsPlus
Examiner Comments

The key features of the energy transfer processes are described clearly in this response, with correct use of technical language.

(b) The website of the delivery company includes the following statement.

| |
|---|
| *If the ice has melted by the time you receive your delivery, this means that energy from the ice has been used to keep the food cold.* |

Explain why the statement made by the company is **not** correct.

**(2)**

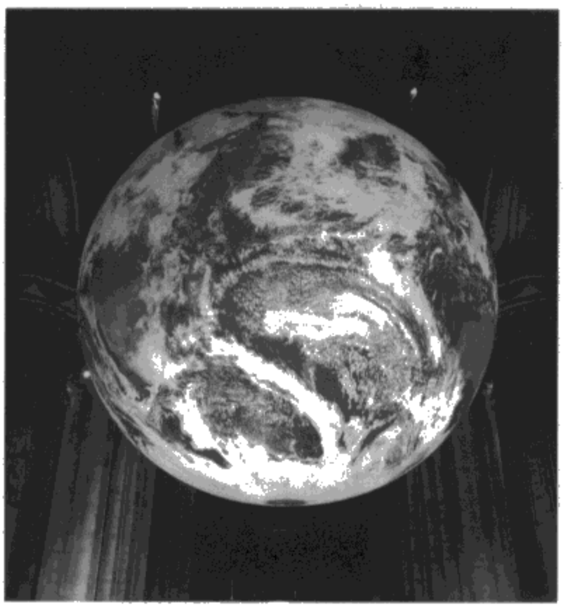
The statement is incorrect because the energy from the ice is used to break intermolecular force between particles, so the ice melts, ~~a~~ to acheive thermal equilibrium with ~~to~~ the surrounding

There are some correct ideas in this response, but they are applied incorrectly to the situation and so no credit is given.

# Question 17(a)

Only a minority of wrong answers were seen, with three quarters of the responses scoring full marks. The equation for the volume of a sphere caused the most problems, as it was clear that some candidates had not learnt this.

**17** The Gaia globe is a three-dimensional model of the Earth, as shown. The inflated globe is suspended from above and is able to rotate.



The globe is filled with nitrogen gas. When fully inflated the globe has a radius of 3.50 m.

(a) Calculate the mass of nitrogen gas needed to exert a pressure of $1.12 \times 10^5$ Pa inside the globe, at a temperature of 22.0 °C.

mass of a nitrogen molecule = $4.67 \times 10^{-26}$ kg

**(5)**

$PV = NKT$ $\quad$ $22 + 273 = 295K$

$1.12 \times 10^5 \times 180 = N \times 1.38 \times 10^{-23} \times 295$

$N = 4.94 \times 10^{27}$ $\quad$ $V = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi \times 3.5^3 = 180m^3$

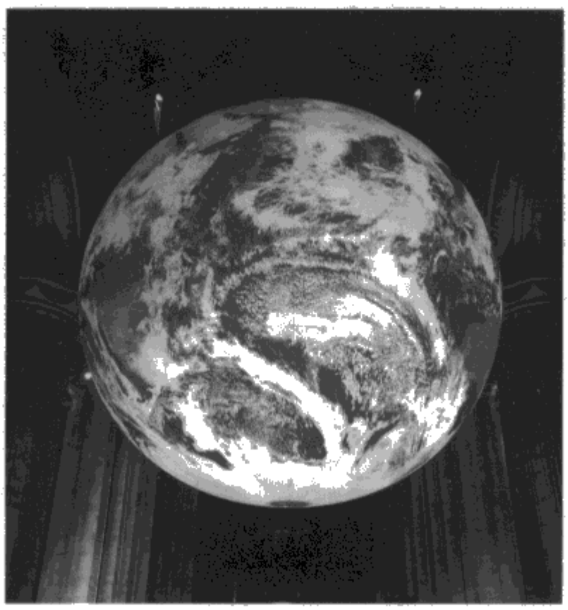
$4.67 \times 10^{-26} \times 4.94 \times 10^{27} = 230.7kg$

Mass of nitrogen gas = 230.7 kg

ResultsPlus
Examiner Comments

This response sets out the solution clearly and succinctly. The response scored all 5 marks.

17 The Gaia globe is a three-dimensional model of the Earth, as shown. The inflated globe is suspended from above and is able to rotate.



The globe is filled with nitrogen gas. When fully inflated the globe has a radius of 3.50 m.

(a) Calculate the mass of nitrogen gas needed to exert a pressure of $1.12 \times 10^5$ Pa inside the globe, at a temperature of 22.0 °C.

mass of a nitrogen molecule = $4.67 \times 10^{-26}$ kg

**(5)**

$pV = NkT$   $V = \frac{4}{3}\pi r^3$   $V = \frac{4}{3}\pi (3.5/2)^3$

$\cancel{k}$ $\frac{1.12 \times 10^5 \times 22.45}{1.38 \times 10^{-23} \times (22 + 273)} = N$   $V = 22.45\ m^3$

$N = \cancel{6.17}\ 6.18 \times 10^{26}$   $6.18 \times 10^{26} \times 4.67 \times 10^{-26} =$

~~28kg~~ 28.84kg

Mass of nitrogen gas = 28.84 kg

ResultsPlus
Examiner Comments

In this response the radius has been halved before being substituted into the expression for the volume. This was seen in a number of scripts and possibly indicates that some candidates were reading the question too quickly and assuming that they had been provided with a value for the diameter. This response scores 3 marks for MP2, MP3 and MP4.

ResultsPlus
Examiner Tip

Read the information given in the question carefully before starting to substitute into equations.

**17** The Gaia globe is a three-dimensional model of the Earth, as shown. The inflated globe is suspended from above and is able to rotate.

The globe is filled with nitrogen gas. When fully inflated the globe has a radius of 3.50 m.

(a) Calculate the mass of nitrogen gas needed to exert a pressure of $1.12 \times 10^5$ Pa inside the globe, at a temperature of 22.0 °C.

mass of a nitrogen molecule = $4.67 \times 10^{-26}$ kg

**(5)**

$V_{globe} = \frac{2}{3}\pi r^2 \rightarrow \frac{2}{3}\pi \times 3{,}5^2 = 25{,}65$

$pV = NkT \rightarrow 1{,}12 \times 10^5 \times 25{,}65 = N \times 1{,}38 \times 10^{-23} \times 22$

$N = \frac{1{,}12 \times 10^5 \times 25{,}65}{1{,}38 \times 10^{-23} \times 22} = 9{,}4625 \times 10^{27}$ molecules of nitrogen

$9{,}46 \times 10^{27} \times 4{,}67 \times 10^{-26} = 441{,}9$ kg

Mass of nitrogen gas = 441,9 kg

ResultsPlus
Examiner Comments

The first error in this response is the use of an incorrect expression for the volume of a sphere. In general the vast majority of responses did attempt a substitution into a correct expression for the volume in this series. A second problem with the response is the failure to convert the temperature from Celsius into Kelvin. The response scored 2 marks for MP2 and MP4.

ResultsPlus
Examiner Tip

Mathematical expressions for area, volume, etc, are not provided for this examination and so these need to be learnt.

# Question 17(b)

The vast majority of candidates were able to use the angular velocity expression, with 90% of responses scoring full marks.

(b) The globe rotates with an angular velocity of $2.76 \times 10^{-2}\,\mathrm{rad\,s^{-1}}$.

Calculate the time taken for the globe to make one complete rotation.

**(2)**

$W = \cancel{\pi}\ \frac{2\pi}{T}$ $\quad T = \frac{2\pi}{W} = \frac{2\pi}{2.76 \times 10^{-2}} = 227.65\ s$

Time taken for one rotation = 227.65 s.

**ResultsPlus**
**Examiner Comments**

This response scored both marks. The answer is given to 5 significant figures, but that is not a problem for a calculation carried out in a theoretical context.

(b) The globe rotates with an angular velocity of $2.76 \times 10^{-2}$ rad s$^{-1}$.

$\omega$

Calculate the time taken for the globe to make one complete rotation.

**(2)**

$T = \frac{2\pi}{\omega}$

$T = 227,65$ secw

$\approx 228$

Time taken for one rotation = 228 seconds

ResultsPlus
Examiner Comments

This response scored 2 marks. The substitution on values into the equation is not shown, but the answer is correct with units and so both MPs are met.

# Question 17(c)

Most responses gained the 'use of' the equation mark, but arithmetic errors meant that only three quarters of the responses seen gained both marks. Common reasons for not scoring MP2 included forgetting to square *r* when inputting numbers into the calculator, using the wrong value for *r*, omitting units or getting a power of 10 error.

(c) A solid sphere has the same diameter as the Gaia globe.

Calculate the mass of the sphere that would give a value of *g*, at its surface, of $9.8\,\mathrm{N\,kg^{-1}}$.

**(2)**

$r = 3.5\,m$ $\quad g = \frac{GM}{r^2}$ $\quad \frac{gr^2}{G} = M$

$\frac{(9.8)(3.5)^2}{(6.67\times10^{-11})} = 1.7999\times10^{12}\,kg$

Mass of sphere = $1.80\times10^{12}\,kg$

**ResultsPlus**
**Examiner Comments**

This response scored both marks. The value substituted for g is 9.8 N kg -1, which is fine. The value given in the data list is 9.81 N kg -1. A value of 10 N kg -1 would not score MP1.

**ResultsPlus**
**Examiner Tip**

Be sure to use the values for data that are supplied in the data list provided with the question paper.

(c) A solid sphere has the same diameter as the Gaia globe.

Calculate the mass of the sphere that would give a value of $g$, at its surface, of $9.8\,\mathrm{N\,kg^{-1}}$.

(2)

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

$$r = \sqrt{\frac{Gm}{g}} = \frac{6.67 \times 10^{-11} \times m}{9.8} = 3.5$$

$$m = 5.14 \times 10^{11}$$

Mass of sphere = $5.14 \times 10^{11}$ kg

## ResultsPlus Examiner Comments

This response has rearranged the field strength equation correctly, but omitted the square root when values are substituted. Hence MP1 is not given. The answer is wrong and so MP2 is not given either. The response scored zero.

## ResultsPlus Examiner Tip

The "use of" mark is awarded when appropriate values are substituted into a correct physical equation. Rearranging an equation does not count as "use of".

(c) A solid sphere has the same diameter as the Gaia globe.

Calculate the mass of the sphere that would give a value of $g$, at its surface, of $9.8\,N\,kg^{-1}$.

**(2)**

$9.8 = \frac{6.67\times10^{-11}\times M}{3.5^2}$ $M = 1.8\times10^{12}\,kg$

$= 1.8\times10^{15}\,g$

Mass of sphere = $1.8\times10^{15}\,g$

**ResultsPlus**
**Examiner Comments**

For some reason the final answer has been given in g rather than kg in this response. The value is correct in these units (and the correct answer in kg is also given) so the response scored both marks.

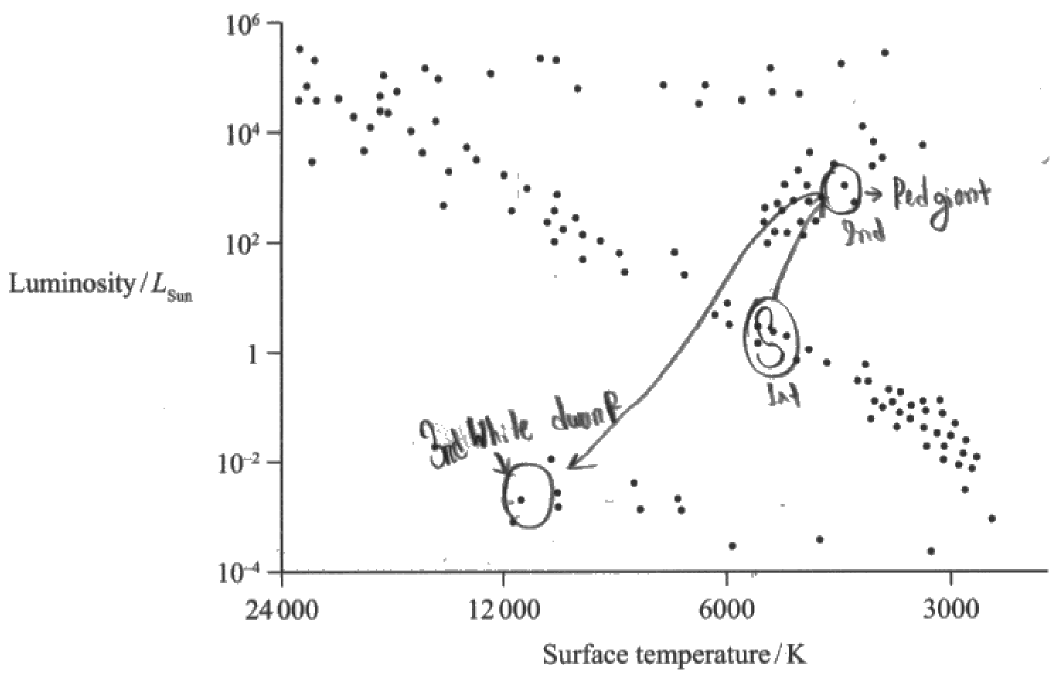
**ResultsPlus**
**Examiner Tip**

Do not convert values into alternative units unless the question requires this.

# Question 18(a)

This was well answered, with two thirds of responses gaining full marks. The Sun was usually marked within the accepted region, although some showed it randomly elsewhere on the main sequence. S ome candidates drew lines from 6000 K and 1 to locate the Sun accurately without issue. The evolution red giant to white dwarf was usually clearly shown, although in some responses the position of the Sun was incorrectly shown as moving up the main sequence before moving across to the red giant region.

**18** The Hertzsprung-Russell diagram shows the relationship between the luminosity and the surface temperature of a range of stars.




(a) The Sun is a main sequence star.

(i) Label the position of the Sun on the diagram with the letter S.

**(1)**

(ii) In the final stages of the Sun's evolution, it will become a white dwarf star.

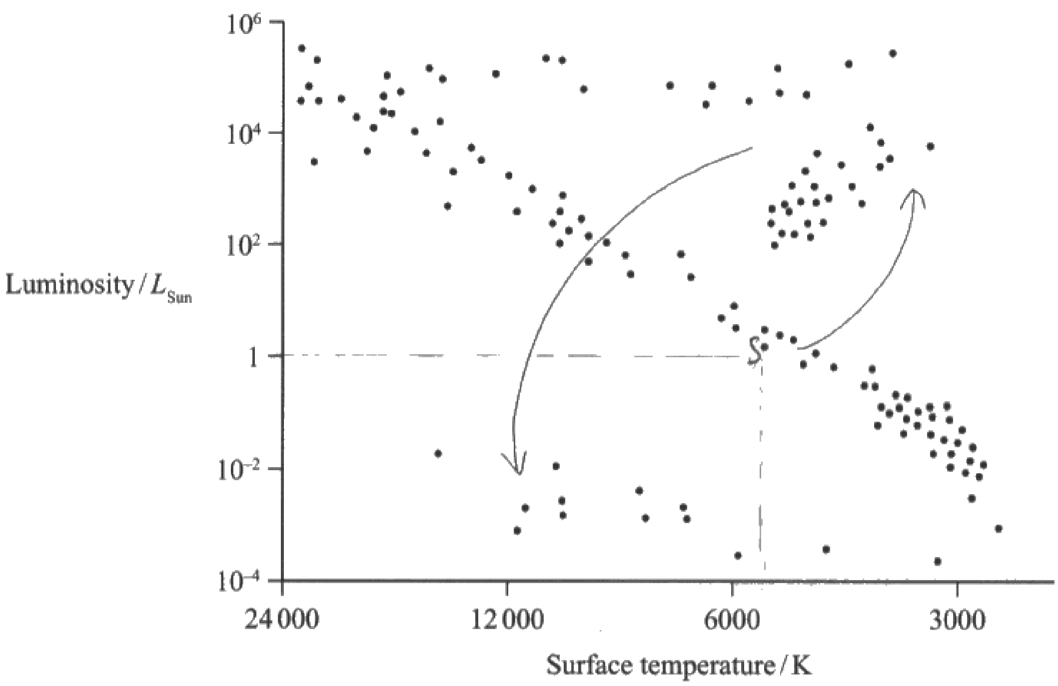
Draw on the diagram a possible path of the Sun as it evolves to a white dwarf star.

**(2)**

ResultsPlus
Examiner Comments

This response shows the Sun in a correct position, with the subsequent evolutionary path also correct and so full marks are scored for both parts of the question.

**18** The Hertzsprung-Russell diagram shows the relationship between the luminosity and the surface temperature of a range of stars.




(a) The Sun is a main sequence star.

(i) Label the position of the Sun on the diagram with the letter **S**.

**(1)**

(ii) In the final stages of the Sun's evolution, it will become a white dwarf star.

Draw on the diagram a possible path of the Sun as it evolves to a white dwarf star.

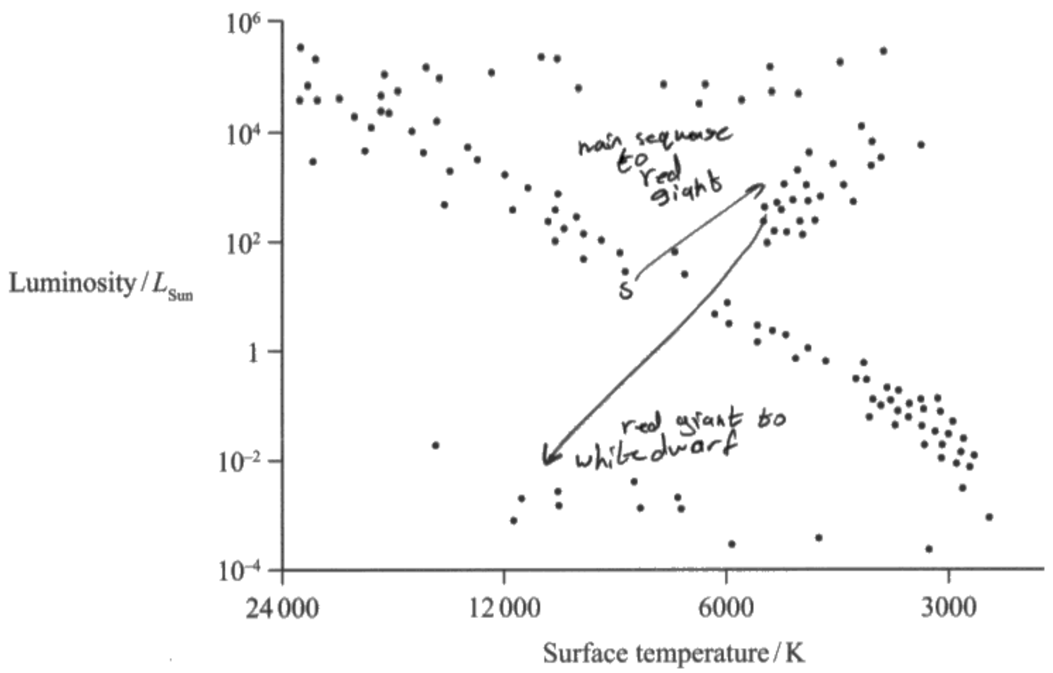
**(2)**

![ResultsPlus Examiner Comments]

**Examiner Comments**

This response scores full marks for each part. A variety of paths were shown for the evolutionary path as the Sun evolves. The key feature of a correct path would be that it starts on the main sequence and ends in the red giant region for the evolution to a red giant, and that it starts on the red giant region and ends on the white dwarf region for the final stage of its evolution. Note that any variation added to the path, such as the position moving up or down the main sequence before moving to the red giant region, would mean that the mark would not be awarded.

**18** The Hertzsprung-Russell diagram shows the relationship between the luminosity and the surface temperature of a range of stars.




(a) The Sun is a main sequence star.

(i) Label the position of the Sun on the diagram with the letter **S**.

**(1)**

(ii) In the final stages of the Sun's evolution, it will become a white dwarf star.

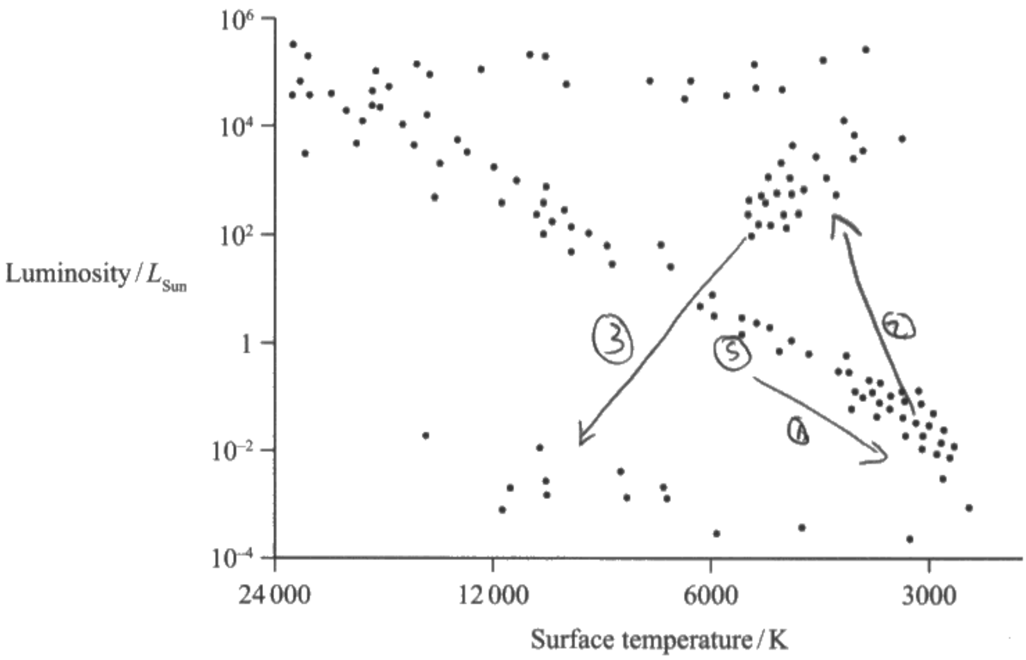
Draw on the diagram a possible path of the Sun as it evolves to a white dwarf star.

**(2)**

**ResultsPlus**
**Examiner Comments**

The Sun is in the wrong position, so (i) scores zero. The path of the Sun as it evolves to a white dwarf is fine and (ii) scores 2 marks.

**18** The Hertzsprung-Russell diagram shows the relationship between the luminosity and the surface temperature of a range of stars.




(a) The Sun is a main sequence star.

(i) Label the position of the Sun on the diagram with the letter **S**.

**(1)**

(ii) In the final stages of the Sun's evolution, it will become a white dwarf star.

Draw on the diagram a possible path of the Sun as it evolves to a white dwarf star.

**(2)**

ResultsPlus
Examiner Comments

The Sun is marked in a correct position, so (i) scores 1 mark. The evolutionary path indicates that the Sun would move down the main sequence before becoming a red giant. This is incorrect. The path from red giant to white dwarf is correct and so (ii) scores 1 mark.

# Question 18(b)

Although the mean mark for this question was only 2, some excellent responses were seen, and most candidates who knew the sequence were able to score marks.

Many candidates correctly mentioned the fusion of hydrogen but often neglected to specify that this process occurs in the core of the star. While most noted that hydrogen runs out, few explained that the fusion rate decreases or stops as a result. Some candidates incorrectly stated that the entire Sun collapses rather than the core. There were also misconceptions about helium fusion. Several candidates said the temperature was high enough for helium fusion without mentioning that the temperature rises first, or they incorrectly claimed that helium fusion causes the temperature to rise. The majority correctly stated that the Sun expands into a red giant, but many did not explain that once helium fusion ceases, the core contracts into a white dwarf.

IC1 and IC4 were most frequently seen in responses. Many responses included detailed descriptions of the energy changes, gravitational forces but missed the point of the question.

IC1 was usually seen.

IC2 was usually only partly seen as most said either hydrogen ran out or fusion ceased but not both.

IC3 was not often see, as most responses stated that the Sun contracted but did not specify the core.

IC4 scored occasionally, although was normally as a part of more detailed information about density and pressure. References to the temperature being high enough for fusion often omitted that the temperature was rising at this point.

IC5 was usually seen.

IC6 was usually only partly seen as references to fusion ceasing or core/star collapsing were omitted.

*(b) Describe the stages in the evolution of the Sun from a main sequence star to a white dwarf star.

(6)

·When the Sun is a main sequence star, hydrogen fusion occurs in core.
·When hydrogen runs out, fusion rate decreases.
·Core contracts, temperature of core increases.
·Temperature of core is high enough for helium fusion.
·Star expands, surface temperature decreases, luminosity increases, it evolves into a red giant, which is on the top right of diagram
·When helium runs out, fusion stops.
Core contracts, surface temperature increases, luminosity decreases, it evolves into a white dwarf, which is on the bottom left of the star.

## ResultsPlus
**Examiner Comments**

This response is clearly expressed and includes all the necessary detail. All IC points are seen, giving 4 content marks. Ideas are linked together logically, giving 2 linkage marks. Response scores 6 marks in total.

## ResultsPlus
**Examiner Tip**

Plan your response to an extended open response question so that you are clear which points you are going to make before you start writing your response.

*(b) Describe the stages in the evolution of the Sun from a main sequence star to a white dwarf star.

**(6)**

In the main sequence sun in the core hydrogen fussion takes place so at the point hydroge fussion comes to end in contoacts than sun starts to expand and cool down and at the point where there's sufficient engery to takes place helium fusion sun becomes an redgiant and helium fusion takes place Then when the helium fusion also comes to an end core contracts and become an white dwarf stars with a greater temperature and a smaller luminosity.

**ResultsPlus**
**Examiner Comments**

This response includes the necessary stages of evolution, but lacks essential detail in places. There is reference to hydrogen fusion coming to an end but without the statement that hydrogen has been used up, so not IC2. Rather than the temperature rising to a point where helium fusion can start there is reference to "sufficient energy", so not IC4. Rather than expanding into a red giant the "Sun becomes a red giant", so not IC5. The response has 3 IC points, so 2 marks for content. There is reasonable linkage of ideas, so 1 linkage mark. This gives a total of 3 marks for this response.

**ResultsPlus**
**Examiner Tip**

Make sure that sufficient detail is included, and use technical vocabulary where appropriate.

# Question 18(c)

About half of the responses seen scored zero, with only a proportion of candidates stating that there is a higher core temperature in massive stars.

This may indicate that many candidates are unaware of the variation in the mass of stars on the main sequence.

However, many candidates correctly stated that massive stars have a greater rate of fusion for MP2.

(c) Explain why the Sun will stay on the main sequence for a much greater time than the most massive main sequence stars.

(2)

The most massive main sequence stars have a high gravitational force, hence they have a high density in the core, and the rate of fusion is high. So they produce higher temperature and luminosity and hence have a shorter main sequence star lifespan ~~compared~~ compared to low mass stars like the Sun.

(Total for Question 18 = 11 marks)

**ResultsPlus**
**Examiner Comments**

This response almost scores full marks. The ideas are a little jumbled, but the idea of a higher temperature in massive main sequence stars is included for MP1. MP2 requires the rate of fusion to be higher in these stars than in the Sun, but in this response the rate of fusion is simply "high". For this reason MP2 is not awarded, and the response scores 1 mark.

(c) Explain why the Sun will stay on the main sequence for a much greater time than the most massive main sequence stars.

**(2)**

Because the sun have ~~less~~ lower mass than the ~~massi~~ massive main sequenies star, the gravitional force is lower, the temperature ~~and density~~ is lower so the rate of fusion will be lower, and ~~to~~ stay on the main sequence for greater time.

ResultsPlus
Examiner Comments

This response gives the converse argument, that the lower temperature and rate of fusion in the Sun means that it stays on the main sequence for a longer time. This is correct alternative physics for this situation and scores both marks.

(c) Explain why the Sun will stay on the main sequence for a much greater time than the most massive main sequence stars.

(2)

More massive star will consume quicker the hydrogen.
It will fuse at a higher rate.

**ResultsPlus**
**Examiner Comments**

There is no reference to temperature in this response, so MP1 is not met. However, the statement that hydrogen will fuse at a higher rate in the more massive stars is good for MP2.

(c) Explain why the Sun will stay on the main sequence for a much greater time than the most massive main sequence stars.

(2)

The Sun has a lot more hydrogen remaining at its core to fuse, and has a lower temperature compared to other main sequence stars. This will increase the time taken to exhaust all its fuel.

ResultsPlus Examiner Comments

This response states that the temperature is lower in the Sun, and so MP1 is met. MP2 is not given, as the response gives a commonly seen incorrect idea, that there is more hydrogen in the Sun to fuse. The response scores 1 mark.

# Question 19

(a)(i) was generally well answered. Although a common mistake was to substitute frequency instead of wavelength into Wien's law. As this was a 'show that' question, some working is expected for the calculation even if full substitutions are not given. In addition, the units are required for MP3 to be awarded.

(a)(ii) This was generally well answered, although some candidates did not fully understand the relationship between average kinetic energy and the absolute temperature.

(b) In most responses a value for the intensity was calculated correctly. However, a common mistake included using the wrong formula, such as calculating the volume or the area of a circle instead of the surface area of a sphere. Another error was to make an incorrect substitution of the distance in the relevant formulas. For MP5 to be awarded a comparison of values had to be included in the calculation.

**19** Tau Ceti is a main sequence star similar to the Sun. Several planets orbit Tau Ceti.

(a) (i) The spectrum of electromagnetic radiation emitted by Tau Ceti has a maximum intensity at a frequency of $5.50 \times 10^{14}$ Hz.

Show that the surface temperature of Tau Ceti is about 5300 K.

**(3)**

$c = f\lambda \therefore \lambda_{max} = \dfrac{(3\times10^{8})}{(5.5\times10^{14})} = \cancel{4} \; 5.454...\times10^{-7}$

$\lambda_{max} T = 2.898\times10^{-3} \quad \therefore \dfrac{1}{T} = \dfrac{5.454...\times10^{-7}}{2.898\times10^{-3}} \quad \therefore T = 5313\,K$

$\approx 5300\,K$

(ii) Calculate the average kinetic energy of gas atoms at the surface of Tau Ceti.

**(2)**

$E_k = \dfrac{3}{2}kT = \dfrac{3}{2}(\cancel{1.6}\; 1.38\times10^{-23})(5313)$

$= 1.099...\times10^{-19}$

$\approx \cancel{1.0}\; 1.10\times10^{-19}\,J$

Average kinetic energy of gas atoms = $1.10\times10^{-19}\,J$

(b) Aita is a planet in orbit around Tau Ceti.

A scientist suggests that Aita receives the same intensity of light from Tau Ceti as the Earth receives from the Sun.

Evaluate the accuracy of this suggestion.

radius of Tau Ceti = $5.52 \times 10^8$ m
distance between Aita and Tau Ceti = $8.05 \times 10^{10}$ m
intensity of light received at the surface of Aita = $1360\,W\,m^{-2}$

**(5)**

~~$I = \frac{L}{4\pi r^2}$~~ ~~$L = A\sigma T^4 = (4\pi)(5.52\times10^8)^2(5.67\times10^{-8})(5313)^4$~~

~~$= 1.729.. \times 10^{26}$~~

~~$\therefore I_A = \frac{L}{4\pi(8.05\times10^{10})^2} = 2124.36..$~~ $I_A = 2124.36..\,Wm^{-2}$

$\neq 1360\,Wm^{-2}$

~~$I_s = \frac{(10^2)}{5800(4\pi}$~~ ~~$L_{sun} \approx L_{TC}$ $\therefore I_{sun} \approx I_{TC}$~~

$I = \frac{L}{4\pi r^2}$ $\rightarrow L = A\sigma T^4$ $\therefore T^4 = \frac{(1360)(4\pi)(8.05\times10^{10})^2}{4\pi(5.52\times10^8)^2(5.67\times10^{-8})}$

$\therefore T = 4752.4K$. $\neq 5300k$

~~and $\neq 5800k$~~

~~$T_{sun} = 5800k$ $E = \frac{3}{2}(1.38\times10^{-23})(5800)$~~ ~~$\therefore$ not same~~

~~$I_{Au} =$ ——— m~~ $\therefore$ ~~$\frac{3}{}$~~ $\therefore$ suggestion inaccurate

luminosity is lower due to dust obstruction $\therefore$ intensity is uncertain

**(Total for Question 19 = 10 marks)**

**ResultsPlus**
**Examiner Comments**

The responses to (a)(i) and (a)(ii) are as per the mark scheme and so score full marks. The temperature is given to 4 significant figures (this is a 'show that' question, and so at least 3 significant figures are required - one more than the value given in the question). The unit is given for the temperature, although this is not necessary in a 'show that' question. The response to (b) uses a method not commonly seen - the surface temperature of the star is calculated and compared with the value given in the question. This is a valid method, and all 5 marks are scored. Note that the reasons given for the difference is not required by the question and so this can be ignored in the response.

**ResultsPlus**
**Examiner Tip**

In a 'show that' question, the answer must be calculated to one more significant figure than the value given in the question.

**19** Tau Ceti is a main sequence star similar to the Sun. Several planets orbit Tau Ceti.

(a) (i) The spectrum of electromagnetic radiation emitted by Tau Ceti has a maximum intensity at a frequency of $5.50 \times 10^{14}$ Hz.

Show that the surface temperature of Tau Ceti is about 5300 K.

**(3)**

$\lambda T = 2.898 \times 10^{-3}$ ~~for~~ ~~$\lambda$~~ $v = f\lambda$

$T = \dfrac{2.898 \times 10^{-3}}{\lambda}$ $\dfrac{3.0 \times 10^{8}}{5.5 \times 10^{14}} = \lambda$

$\lambda =$ ~~0.~~ $5.45 \times 10^{-7}$ m

$T = \dfrac{2.898 \times 10^{-3}}{5.45 \times 10^{-7}} = 5317\ K = 5300\ K$

(ii) Calculate the average kinetic energy of gas atoms at the surface of Tau Ceti.

**(2)**

$E = \frac{3}{2} k T$

$E = \frac{3}{2}(1.38 \times 10^{-23})(5317) = 1.1 \times 10^{-19}$ J

Average kinetic energy of gas atoms = $1.1 \times 10^{-19}$ J

(b) Aita is a planet in orbit around Tau Ceti.

A scientist suggests that Aita receives the same intensity of light from Tau Ceti as the Earth receives from the Sun.

Evaluate the accuracy of this suggestion.

radius of Tau Ceti = $5.52 \times 10^8$ m
distance between Aita and Tau Ceti = $8.05 \times 10^{10}$ m
intensity of light received at the surface of Aita = $1360\ \mathrm{W\,m^{-2}}$

(5)

- Luminosity = $I \times 4\pi d^2$

~~Lumin~~ $L = 1360 \times 4\pi(8.05\times10^{10})^2 = \cancel{1.12}\ 1.11\times10^{26}$ W of Tau Ceti

- $L = \sigma A T^4$

$T = \sqrt[4]{\dfrac{L}{\sigma A}}$

$T = \sqrt[4]{\dfrac{1.11\times10^{26}}{5.67\times10^{-8}\times \cancel{\tfrac{4}{3}\pi(5.52\times10^8)^3}\ 4\pi(5.52\times10^8)^2}}$

$T =$ ~~4?K~~ 4755 K of Tau Ceti

∴ if Aita receives the same intensity of light from Tau Ceti as the Earth from Sun. The Surface Temperature of Tau Ceti should be the same as the Sun. But Tau Ceti's surface temperature is 4755 K whereas the Sun's is 5800 K to ~~600K~~ 6000 K. So the suggestion is incorrect.

**ResultsPlus**
**Examiner Comments**

Both parts of (a) score full marks. The response to (b) attempts to make a comparison of temperatures. The value calculated for the surface temperature of Tau Ceti is correct. However, instead of comparing this with the value given in the question the comparison with the surface temperature of the Sun is made. This is invalid on two counts. Firstly, the distance from star to planet are different for each case, and so a comparison of temperatures of the two stars is not valid. Secondly, the surface temperature of the Sun is not given in the question. The comparison must be made between values provided. The response scores the first 4 marking points.

**ResultsPlus**
**Examiner Tip**

In an 'evaluate' question you should make a comparison in your conclusion between two values given or derived from data in the question.

**19** Tau Ceti is a main sequence star similar to the Sun. Several planets orbit Tau Ceti.

(a) (i) The spectrum of electromagnetic radiation emitted by Tau Ceti has a maximum intensity at a frequency of $5.50 \times 10^{14}$ Hz.

Show that the surface temperature of Tau Ceti is about 5300 K.

**(3)**

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

$T = \dfrac{2.898 \times 10^{-3}}{5.45 \times 10^{-7}}$

$T = 5313 K$

$T \approx 5310 K$

~~$f\lambda$~~

$v = f\lambda$

$\lambda = \dfrac{3 \times 10^{8}}{5.5 \times 10^{14}}$

$\lambda = 5.45 \times 10^{-7} m$

(ii) Calculate the average kinetic energy of gas atoms at the surface of Tau Ceti.

**(2)**

$E_K = 3/2\, kT$

$= 3/2 \times 1.38 \times 10^{-23} \times 5313$

$= 1.0998$

$\approx 1.1 \times 10^{-19} J$

Average kinetic energy of gas atoms = ~~$1.1 \times 10^{-19}$~~ $1.1 \times 10^{-19}$ J

(b) Aita is a planet in orbit around Tau Ceti.

A scientist suggests that Aita receives the same intensity of light from Tau Ceti as the Earth receives from the Sun.

Evaluate the accuracy of this suggestion.

radius of Tau Ceti = $5.52 \times 10^8$ m
distance between Aita and Tau Ceti = $8.05 \times 10^{10}$ m
intensity of light received at the ~~surface of Aita~~ earth from the Sun = 1360 W m$^{-2}$

(5)

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

$L = \sigma A T^4$

$= 5.67 \times 10^{-8} \times 4\pi \times (5.52 \times 10^8)^2 \times (5310)^4$

$L = 1.726 \times 10^{26}$ W

$I = \frac{1.726 \times 10^{26}}{4\pi \times (\cancel{5.52 \times 10^8}\ 8.05 \times 10^{10})^2}$

$I = \cancel{1876.9}$ 1901.0 W m$^{-2}$

~~1877~~ 1901.0 > 1360 ∴ not an accurate statement

**ResultsPlus**
**Examiner Comments**

The responses to (a)(i) and (a)(ii) are correct and score full marks. There is an arithmetic error in (b) and so MP4 is not given. However, the calculated value is compared with an appropriate value given in the question and a conclusion made and so MP5 is awarded. Hence (b) scores 4 marks.

**ResultsPlus**
**Examiner Tip**

Check calculations carefully for arithmetic errors.

**19** Tau Ceti is a main sequence star similar to the Sun. Several planets orbit Tau Ceti.

(a) (i) The spectrum of electromagnetic radiation emitted by Tau Ceti has a maximum intensity at a frequency of $5.50 \times 10^{14}$ Hz.

Show that the surface temperature of Tau Ceti is about 5300 K.

**(3)**

$v = f\lambda$ $\quad \dfrac{2.898 \times 10^{-3}}{5.45 \times 10^{-7}} = \boxed{5313\text{ K}}$

$\dfrac{3 \times 10^{8}}{6.5 \times 10^{14}} = 5.45 \times 10^{-7}$

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

(ii) Calculate the average kinetic energy of gas atoms at the surface of Tau Ceti.

**(2)**

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

$3/2\,(1.38 \times 10^{-23})(5313) =$

Average kinetic energy of gas atoms = $1.1 \times 10^{-19}$ J

(b) Aita is a planet in orbit around Tau Ceti.

A scientist suggests that Aita receives the same intensity of light from Tau Ceti as the Earth receives from the Sun.

Evaluate the accuracy of this suggestion.

radius of Tau Ceti = $5.52 \times 10^{8}$ m
distance between Aita and Tau Ceti = $8.05 \times 10^{10}$ m
intensity of light received ~~at the surface of Aita~~ = 1360 W m$^{-2}$
at the earth from the sun

(5)

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

$I = \frac{\sigma 4\pi r^2 T^4}{4\pi d^2} \rightarrow I = \frac{\sigma r^2 T^4}{d^2}$

$\frac{(5.67 \times 10^{-8})(5.52 \times 10^{8})^2 (6313)^4}{(8.05 \times 10^{10})^2}$

$\rightarrow 2124 \text{ W m}^{-2}$

$2124 > 1360$

Aita reciere mor intensity of light from tau Ceti than the earth from the sun.

**ResultsPlus**
**Examiner Comments**

This response scores full marks for each part. Note that in (a)(i) the steps in the solution are a little unclear. However, the steps can be seen, and the calculated value is correct and to an appropriate number of significant figures, so all marks are awarded.

**ResultsPlus**
**Examiner Tip**

In a 'show that' question the method of working must be seen, so show the steps in your method clearly.

# Question 20(a)

Most candidates knew the nucleon number and proton number of an alpha particle and could balance both the top and the bottom lines of the nuclear equation. About 90% of responses seen scored both marks.

# Question 20(b)

(i) This question was generally well answered. The correct values were used in most responses, but a common mistake was to calculate the mass difference incorrectly, which led to errors in the final answer.

Some candidates tried to scale the masses of the nucleons up to the entire nucleus using nucleon numbers, or did not quote the final answer to enough significant figures.

As this was a 'show that' question, some working is expected for the calculation even if full substitutions are not given. In addition, the units are required for MP3 to be awarded.

(ii) Candidates struggled with this question as many had no real understanding of the relationship between power and energy/activity as presented in this question. Most managed to find a decay constant or a number of atoms but it was clear they didn't understand why. Nearly all followed with some attempt to use these numbers, typically in the exponential equation, which resulted in them arriving back at the same number. The final solution, realising that the activity needed to be calculated and used to find the power output, was only seen in the very best responses. The main challenge was in making the connection between activity and power, which prevented candidates from reaching the correct final answer.

(iii) Many candidates did not use the correct formula to calculate the power, which led to incorrect answers.

(b) The space probe was powered by the energy released in the decay of plutonium-238.

(i) Show that the energy released in the decay of one nucleus of plutonium-238 is about 5.7 MeV.

mass of plutonium nucleus = $3.9516 \times 10^{-25}$ kg
mass of uranium nucleus = $3.8851 \times 10^{-25}$ kg
mass of alpha particle = $6.6399 \times 10^{-27}$ kg

**(4)**

$E = \Delta m c^2$

$234 \times 3.8851 \times 10^{-25} + 6.6399 \times 10^{-27} \times 4 = \cancel{2.41 \times 10^{-48}\ kg}\ 9.1 \times 10^{-23}\ kg$

$238 \times 3.9516 \times 10^{-25} = 9.4 \times 10^{-23}\ kg$

$9.4 \times 10^{-23} - 9.1 \times 10^{-23} = 3 \times 10^{-24}\ kg$ $\quad 3 \times 10^{-24} \times (3 \times 10^{8})^2$

$1kg = \cancel{\frac{(3 \times 10^8)^2}{1.6 \times 10^{-19}}}\ eV = \cancel{\frac{(3 \times 10^8)^2}{1.6 \times 10^{-25}}\ MeV}$

$3.8851 \times 10^{-25} + 6.6399 \times 10^{-27} = 3.95 \times 10^{-25}\ kg$

$3.9516 \times 10^{-25} - 3.95 \times 10^{-25} = 1.6 \times 10^{-28}\ kg.$

$1.6 \times 10^{-28} \times (3 \times 10^{8})^2 =$

(ii) When the space probe was launched, the decay of plutonium-238 produced a power of 550 W.

A website states that there was 1.00 kg of plutonium-238 when the space probe was launched.

Deduce whether the website statement is accurate.

number of atoms in 0.238 kg of plutonium = $6.00 \times 10^{23}$
half-life of plutonium-238 = 87.7 years
1 year = $3.15 \times 10^7$ s

**(5)**

$t_{\frac{1}{2}} = 87.7 \times 3.15 \times 10^7 = 2.76 \times 10^9$ s

$W = \cancel{E_k}\ E = 5.7 \times 10^6 \times 1.6 \times 10^{-19} = 9.12 \times 10^{-13}$ J

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

$W = Pt \quad P = \frac{W}{t} \quad t = \frac{W}{P} = \frac{9.12 \times 10^{-13}}{550}$

$\lambda = \frac{\ln 2}{t_{\frac{1}{2}}} = \frac{\ln 2}{2.76 \times 10^9} = 2.511 \times 10^{-10}\ s^{-1}$

$= 1.66 \times 10^{-15}$ s

$N = 6.00 \times 10^{23} \times e^{-2.511 \times 10^{-10} \times 1.66 \times 10^{-15} s}$

$N = 6 \times$

$W = 5.7 \times 10^6 \times 1.6 \times 10^{-19} \times 238 = 2.2 \times 10^{-10}$ J

$t = \frac{W}{P} = \frac{2.2 \times 10^{-10}}{550} =$

(iii) The space probe took 74 months to travel to Jupiter.

Calculate the power produced when the space probe arrived at Jupiter, due to the decay of plutonium-238.

1 month = $2.63 \times 10^6$ s

**(2)**

$t = 74 \times 2.63 \times 10^6 = 1.95 \times 10^8$ s

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

**ResultsPlus**
**Examiner Comments**

In the response to (b)(i) the mass difference is calculated incorrectly. In common with many responses seen, the masses provided in the question are multiplied by nucleon numbers. However, there is use of the Einstein equation to calculate an energy, so MP2 can be given. There is no evidence of a conversion from J to eV and the final answer is incorrect, so the response scores 1 mark. In the response to (b)(ii) the decay constant is calculated correctly, but this is used with the exponential decay equation rather than the activity equation. This error was seen in a number of responses to this question. The response to (b)(ii) scores 1 mark. For (b)(iii) there is a conversion from months to seconds but nothing else, and so this scores zero.

(b) The space probe was powered by the energy released in the decay of plutonium-238.

(i) Show that the energy released in the decay of one nucleus of plutonium-238 is about 5.7 MeV.

mass of plutonium nucleus = $3.9516 \times 10^{-25}$ kg
mass of uranium nucleus = $3.8851 \times 10^{-25}$ kg
mass of alpha particle = $6.6399 \times 10^{-27}$ kg

**(4)**

mass defect: $3.9516 \times 10^{-25} - (3.8851 \times 10^{-25} + 6.6399 \times 10^{-27})$

$= 1.01 \times 10^{-29}$ kg

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

(in Joules) $\Delta E = 1.01 \times 10^{-29} \times (3 \times 10^{8})^2 = 9.09 \times 10^{-13}$ J

in eV $= \frac{9.09 \times 10^{-13}}{1.6 \times 10^{-19}} = 5.68125 \times 10^{6}$ eV

$= 5.68$ MeV

(ii) When the space probe was launched, the decay of plutonium-238 produced a power of 550 W. → 550 J/sec

A website states that there was 1.00 kg of plutonium-238 when the space probe was launched.

Deduce whether the website statement is accurate.

number of atoms in 0.238 kg of plutonium = $6.00 \times 10^{23}$
half-life of plutonium-238 = 87.7 years
1 year = $3.15 \times 10^{7}$ s

**(5)**

$\lambda = \frac{\ln 2}{t_{1/2}} \rightarrow \lambda = \frac{\ln 2}{87.7 \times 3.15 \times 10^{7}} = 2.509 \times 10^{-10}$ sec$^{-1}$

number of $^{238}_{94}Pu$ atoms in $\underline{1}$ kg :

$6 \times 10^{23} \div 0.238 = 2.521 \times 10^{24}$ Pu atoms

$A = N\lambda$

$A = 2.52 \times 10^{24} \times 2.509 \times 10^{-10} = 6.32 \times 10^{14}$ Bq

$6.32 \times 10^{14}$ decay / sec

energy per decay: $9.09 \times 10^{-13}$ J

energy per second: $9.09 \times 10^{-13} \times 6.32 \times 10^{14}$

$= 574.488$ W

$574.488 \text{ W} \approx 550 \text{ W}$

it is accurate.

(iii) The space probe took 74 months to travel to Jupiter.

Calculate the power produced when the space probe arrived at Jupiter, due to the decay of plutonium-238.

1 month = $2.63 \times 10^6$ s

**(2)**

Second in 74 months = $74 \times 2.63 \times 10^6 = 192.62 \times 10^6$ s

Energy produced: ~~2.63 x10~~ $192.62 \times 10^6 \times 574.438$

~~= 1.19x~~ $= 1.118 \times 10^{11}$ J

Power produced = $1.118 \times 10^{11}$ J

## ResultsPlus
### Examiner Comments

The response to (b)(i) and (b)(ii) are correct and so score full marks. In (b)(iii) the number of seconds in 74 months is calculated, but this needs to be used in the exponential equation with the value of the decay constant calculated in (ii). In common with many responses seen, this was not understood. Hence (b)(iii) scored zero.

## ResultsPlus
### Examiner Tip

In linked parts to a question, values calculated in one part may be needed for use in subsequent parts.

(b) The space probe was powered by the energy released in the decay of plutonium-238.

(i) Show that the energy released in the decay of one nucleus of plutonium-238 is about 5.7 MeV.

mass of plutonium nucleus = $3.9516 \times 10^{-25}$ kg
mass of uranium nucleus = $3.8851 \times 10^{-25}$ kg
mass of alpha particle = $6.6399 \times 10^{-27}$ kg

**(4)**

~~P-90p+148n~~ $\Delta m = (3.9516\times10^{-25}) - (3.8851\times10^{-25} + 6.6399\times10^{-27})$

~~90p-90(~~ $\therefore \Delta m = 1.01\times10^{-29}$ Kg

$\Delta E = \Delta m c^2 \quad \therefore \Delta E = (1.01\times10^{-29})(3\times10^{8})^2 = 9.09\times10^{-13}$ J

$\frac{9.09\times10^{-13}}{1.6\times10^{-19}} = 5.68125\times10^{6}$ eV

$= 5.68125$ MeV $\approx 5.68$ MeV

(ii) When the space probe was launched, the decay of plutonium-238 produced a power of 550 W.

A website states that there was 1.00 kg of plutonium-238 when the space probe was launched.

Deduce whether the website statement is accurate.

number of atoms in 0.238 kg of plutonium = $6.00 \times 10^{23}$
half-life of plutonium-238 = 87.7 years
1 year = $3.15 \times 10^{7}$ s

**(5)**

$\lambda = \frac{\ln 2}{t_{1/2}}$ $A = \lambda N$ atoms in 1 kg = $\frac{6.00 \times 10^{23}}{0.238} = 2.521008403 \times 10^{24}$ atoms

$A = \frac{N \ln 2}{t_{1/2}}$ ∴ $A = \frac{2.521... \times 10^{24} \times \ln 2}{87.7 \times 3.15 \times 10^{7}} = 6.325423493 \times 10^{14}$ Bq

Energy per second $= (6.325... \times 10^{14}) \times (5.68125 \times 10^{6} \times 1.6 \times 10^{-19})$
$= 574.98$ W $\approx 575$ W

~~550 W = 550 W~~ 550 W produced ~~550 J s^{-1}~~

∴ 575 W ≠ 550 W

so statement is inaccurate

website needs fact check.

(iii) The space probe took 74 months to travel to Jupiter.

Calculate the power produced when the space probe arrived at Jupiter, due to the decay of plutonium-238.

1 month = $2.63 \times 10^6$ s

(2)

~~$A = A_0 e^{-\lambda t}$~~ $P = P_0 e^{-\lambda t}$ $\therefore P = 550 e^{\frac{-\ln 2}{87.7 \times 12} \times 74}$

$P = 523.8363408$ W

$\approx 524$ W

Power produced = 524 W

ResultsPlus
Examiner Comments

Responses to each part of this question are correct and so the response gains full marks.

## Question 20(c)

(c) Responses to this question were generally poor, with about three quarters of the responses seen scoring zero. While there was a small number of good responses that gained full marks, the majority of candidates failed to mention the inverse square law, which was essential to answering the question correctly.

(c) Jupiter is much further away from the Sun than Mars is. A space probe to Mars was powered by solar cells.

Suggest why solar cells were **not** suitable for a space probe travelling to Jupiter.

**(2)**

The space probe is traveling away from the sun. Light obeys inverse square law. Since the probe need to go very far away from the sun it will recieve very low intensity of light and generate insufficient power.

**ResultsPlus**
**Examiner Comments**

This response scored 2 marks. There is a reference to the inverse square law for MP1, and the reference to a very low intensity and insufficient power gives two ways of awarding MP2.

(c) Jupiter is much further away from the Sun than Mars is. A space probe to Mars was powered by solar cells.

Suggest why solar cells were **not** suitable for a space probe travelling to Jupiter.

**(2)**

The space probe will be too far away from the Sun, and the radiation emitted by the Sun couldn't reach the solar cells to produce energy for space probe to travel to Jupiter

**ResultsPlus**
**Examiner Comments**

This response scored zero. There is no reference to the inverse square law and rather than making it clear that the intensity of radiation would be too low the ambiguous statement "radiation emitted by the Sun couldn’t reach the solar cells" is made.

# Paper Summary

Based on their performance on this paper, candidates should:

- Ensure they have a thorough knowledge of the physics for this unit.
- Read the question carefully and answer what is asked.
- Formulate a response that is consistent with the command word used in the question.
- Be particularly careful to use appropriate scientific terminology in questions which ask for a description or explanation.
- Include all substitutions and all stages in the working in 'show that' questions.

# Grade boundaries

Grade boundaries for this, and all other papers, can be found on the website on this link: https://qualifications.pearson.com/en/support/support-topics/results-certification/grade-boundaries.html

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