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June 2018

IAL Physics WPH05 01

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Introduction

The assessment structure of WPH05 mirrors that of other units in the specification. It consists of 10 multiple choice questions, a number of short answer questions and some longer, less structured questions. As 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.

This paper gave students the opportunity to demonstrate their understanding of a wide range of topics from this unit, with all of the questions eliciting responses across the range of marks. However marks for questions 12(b), 13(b), 15(c), 16(a)(ii), 17(a)(ii), 17(c), and 18(d)(i-ii) tended to be clustered at the lower end of the scale.

Calculation questions gave students an opportunity to demonstrate their problem solving skills to good effect. Some very good responses were seen for such questions, with accurate solutions which were clearly set out. Occasionally in calculation questions the final mark was lost due to a missing unit.

Once again there were examples of students disadvantaging themselves by not actually answering the question, or by not expressing themselves using suitably precise language. This was particularly the case in questions where they were required to explain or suggest, such as 13(b), 16(a)(ii) and 17(a)(ii) where students sometimes had knowledge of the topic, but could not express it accurately and succinctly. Students could most improve by ensuring they read the question very carefully before they begin their response, describe all aspects in sufficient detail and always use appropriate specialist terminology.

This unit includes a number of topics which have been met at GCSE but require a much greater depth of knowledge and understanding than at that level. On this paper the most significant example of this was Question 12 about the absorption of ionising radiation. Far too many students scored very poorly on 12(b) because they showed only a GCSE understanding of the topic. This suggests that centres might like to review how they teach this topic.

There were two questions testing knowledge of the meaning of scientific terms, 17(a)(i) on binding energy and 18(a) on simple harmonic motion. The responses to both these questions showed scientific terminology being used incorrectly or with insufficient precision. It is important that complete and accurate definitions of such terms are learned.

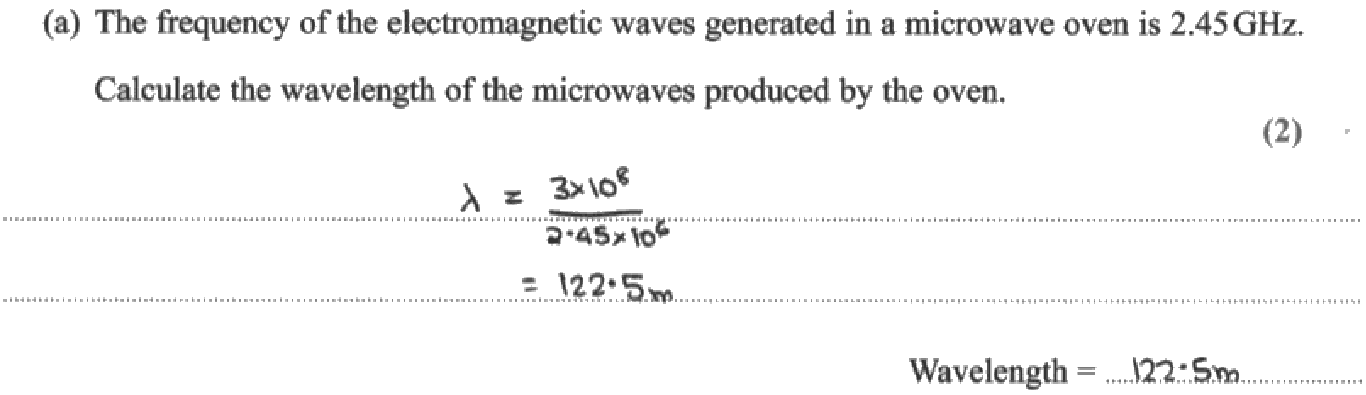
The space allowed for responses was usually sufficient. If more space is needed students should not attempt to squash additional words around the answer space provided but should either use supplementary answer sheets or find an empty page on the question paper. For the latter it is essential to direct the examiner to where that answer may be found.

The response to the multiple choice questions was good.

There was some evidence of students learning previous schemes in the expectation of earning marks. Students should be encouraged to work with mark schemes in preparation for their exam. However, it is important that they understand that mark schemes are written for examiners, and so sometimes refer to what examiners expect to see rather than giving a complete answer. A mark scheme written for one question on a particular topic will almost certainly not be appropriate as an answer to a different question even though it is on the same topic.

Question 11 (a)

Most students found this a straightforward calculation using $v = f\lambda$ and scored full marks. The most common error was in converting the units of frequency from GHz to Hz.



(a) The frequency of the electromagnetic waves generated in a microwave oven is 2.45 GHz.

Calculate the wavelength of the microwaves produced by the oven.

(2)

$\lambda = \frac{3\times10^8}{2\cdot45\times10^6}$

$= 122\cdot5\text{m}$

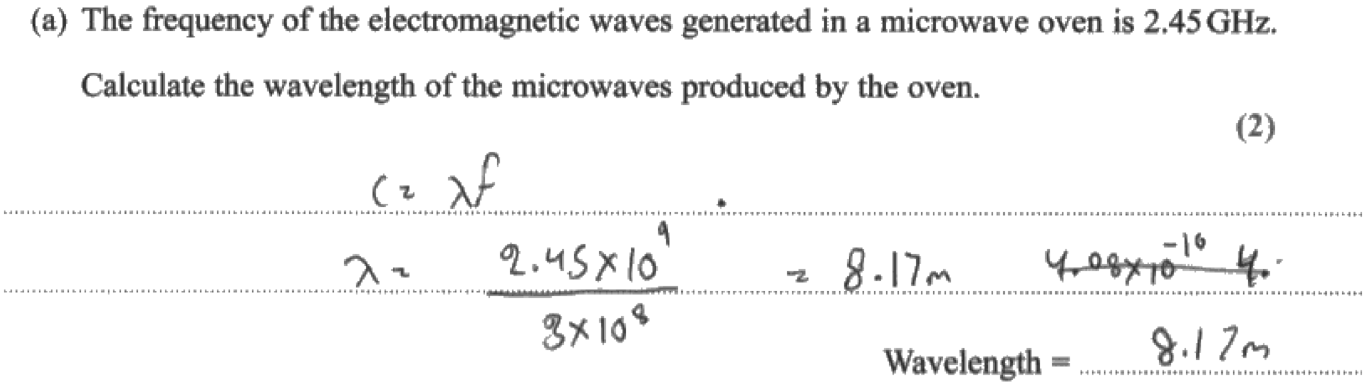
Wavelength = 122·5m

ResultsPlus
Examiner Comments

The values of wavelength and frequency have been substituted into a correctly rearranged equation but the conversion from GHz to Hz has been done by multiplying by 10^6 instead of 10^9. The final answer has a power of ten error but the first mark is scored.

ResultsPlus
Examiner Tip

Make sure that the meaning of all the standard prefixes are thoroughly learned.



(a) The frequency of the electromagnetic waves generated in a microwave oven is 2.45 GHz.

Calculate the wavelength of the microwaves produced by the oven.

(2)

$c = \lambda f$

$\lambda = \frac{2.45\times10^9}{3\times10^8} = 8.17\text{m}$ ~~4.08×10^{-16} 4.~~

Wavelength = 8.17m

ResultsPlus
Examiner Comments

This student has attempted to use the correct equation, has the correct conversion to Hz but has not rearranged the equation correctly and so the values of *c* and *f* have been substituted the wrong way round giving an incorrect final answer. Neither mark can be scored.

ResultsPlus
Examiner Tip

Substitute values into the equation before rearranging.

Question 11 (b) (i)

The majority of responses showed confident use of the three equations, arriving at the correct answer either by comparing powers or energies. There were a number who arrived at an answer of 25% instead of 75% because they used 'wasted' energy or power instead of the 'useful' energy or power in their calculation of efficiency.

A small minority are muddled with the use of Celsius and Kelvin temperatures. Some of these do not realise that because the size of a degree is the same on both scales, a temperature difference is the same whichever scale is used and therefore there is no need to convert to kelvin before subtracting. There were a few that calculated the temperature difference correctly but then attempted to convert to kelvin by adding 273.

(i) Calculate the efficiency of the microwave oven.

(3)

specific heat capacity of water = 4190 J kg^{-1} K^{-1}

~~$E = (225 \times 10^{-3}$~~

$E = (225 \times 10^{-3}) \times 4190 \times (67.5 - 15.0)$

$= 49494.38$

Output Power $= \frac{49494}{120}$

$= 412.45$

Efficiency $= \frac{412.45}{500} \times 100$

$= 82.5\%$

Efficiency = 82.75%

ResultsPlus
Examiner Comments

In this response, the energy used to raise the temperature of the water has been correctly calculated using the specific heat capacity and the corresponding value of the useful power found. However, when substituting into the efficiency equation the microwave oven power has been used as 500W instead of the 550W given in the question, a transposition error. The final answer is therefore incorrect but the first two marks have been awarded.

ResultsPlus
Examiner Tip

Check carefully when copying numbers from the question into your calculation.

(i) **Calculate the efficiency of the microwave oven.**

(3)

specific heat capacity of water = 4190 J kg^{-1} K^{-1}

$P \times t = mc\Delta\theta$ $\qquad P = \frac{mc\Delta\theta}{t}$

$$P = \frac{\frac{225}{1000} \times 4190 \times (67.5-15)}{120} = 412.5W$$

Efficiency = ~~energy~~ $\frac{\text{power output} - \text{power input}}{\text{power input}} \times 100$

$= \frac{550 - 412.5 \times 100}{550}$

$= 25.0\%$

Efficiency = 25.0%

ResultsPlus
Examiner Comments

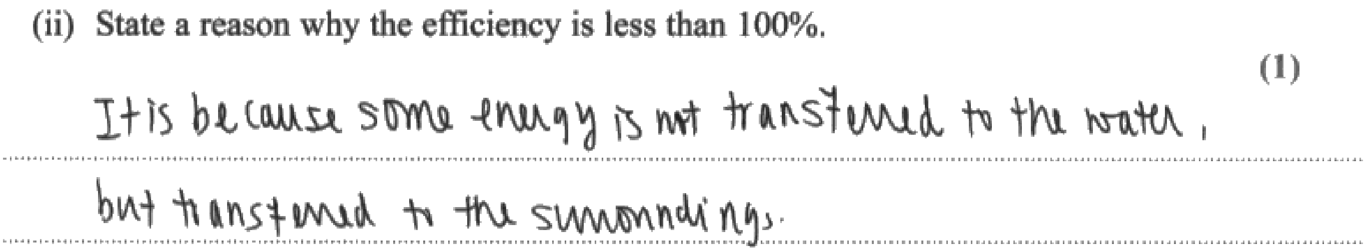
The useful power of the microwave has been correctly calculated but in one stage. However the use of the efficiency equation is not correct because the wasted power has been used instead of the useful power. First mark only is scored.

ResultsPlus
Examiner Tip

Check 'wordy' equations like this carefully before substitution. Remember that the equations are given at the back of the question paper.

Question 11 (b) (ii)

This question requires a response that shows a greater understanding of the physics of this situation than the very simple 'heat lost' answer, which would not score. We are looking for an answer that makes it clear that not all the energy supplied to the microwave oven is used to raise the temperature of the water. This can be expressed in a number of ways, as in the mark scheme. The most common successful responses involved energy being transferred from the water to the beaker or more generally, energy transferred from the water to its surroundings.



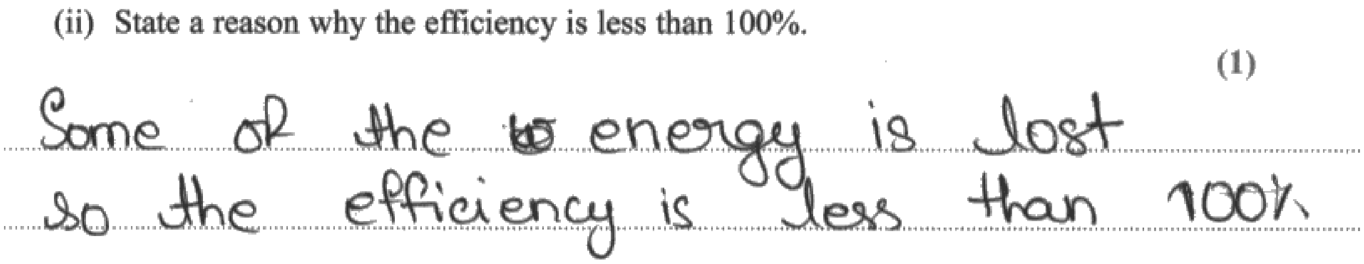
(ii) State a reason why the efficiency is less than 100%.

(1)

It is because some energy is not transferred to the water, but transferred to the surroundings.

ResultsPlus
Examiner Comments

This is acceptable for the mark.



(ii) State a reason why the efficiency is less than 100%.

(1)

Some of the ~~to~~ energy is lost so the efficiency is less than 100%

ResultsPlus
Examiner Comments

It is insuffient and indeed, incorrect to say that energy is 'lost'. We need to know where the energy is being transferred to.

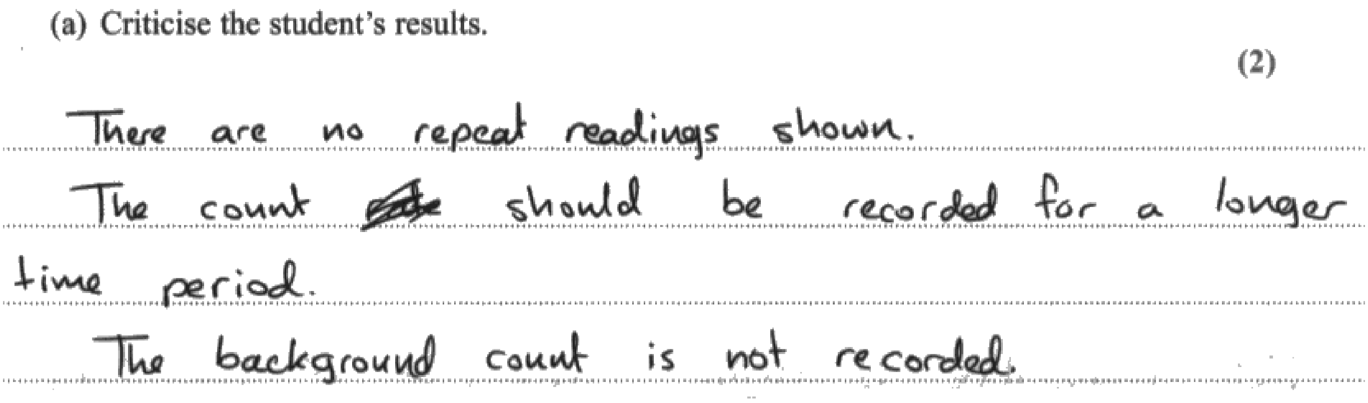
Question 12 (a)

The most important criticism of the results presented in the question is that there is no indication that the student has taken the background count. Whilst the majority of students realised this, some did not use sufficiently precise language to score the first mark. There were two other criticisms, either of which scored the second mark, the lack of repeat readings or that the count should have been recorded for a longer period of time. Most students mentioned at least one of these.

Other common suggestions that did not score

·No units. But 'Count recorded for 2 minutes' does not have a unit.

·Inconsistent number of significant figures. But, the 'Count recorded for 2 minutes' must always be a whole number. The number of significant figures is irrelevant.



(a) Criticise the student's results.

(2)

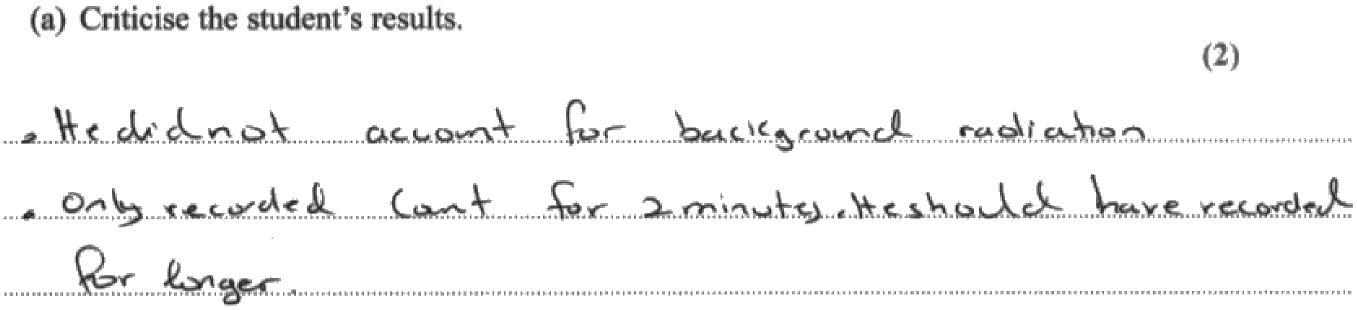
There are no repeat readings shown.

The count should be recorded for a longer time period.

The background count is not recorded.

ResultsPlus
Examiner Comments

This is an example of a response that has all three points from the mark scheme and scores 2.



(a) Criticise the student's results.

(2)

- He did not account for background radiation
- Only recorded count for 2 minutes. He should have recorded for longer.

ResultsPlus
Examiner Comments

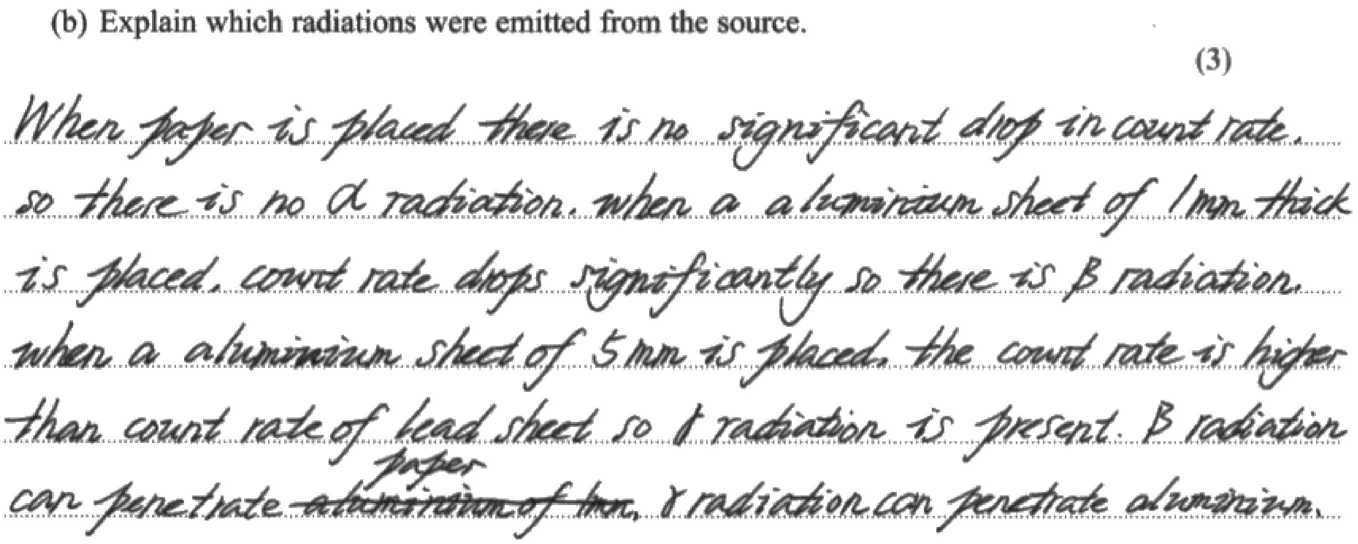
The first sentence is not expressed well enough to score the first mark. We need to know exactly what the students thinks is missing, in other words we need to be told what 'he did not account for background radiation' means. The second mark is scored.

Question 12 (b)

This question required students to study a table of experimental data of recorded count rates for a radioactive source with different absorbers. They were then asked to explain which radiations were emitted from the source. At GCSE students learn that alpha radiation is absorbed by paper, beta radiation is absorbed by a few mm aluminium and gamma radiation is mostly absorbed by several cm of lead but this is insufficient to answer this question. At GCE we expect them to have a more sophisticated understanding of the absorption process, that absorption depends on thickness as well as material, that beta would be completely absorbed by about 3mm aluminium and that some gamma would be absorbed by 5mm aluminium.

Most responses showed little more than a basic GCSE understanding. The most common mark to be scored was for realising that because of the random nature of radioactivity, the change in the count rate caused by paper was not significant and therefore no alpha radiation was emitted. Some students were able to make the comparison between the count rate for 5mm aluminium and 5mm lead, and then conclude that gamma radiation was emitted for the 3rd mark. It was rare to see a response that showed understanding that it was the decrease in count rate caused by the 1mm aluminium that shows the presence of beta radiation for the 2nd mark.

The alternative mark scheme for the 3rd mark was designed for the exceptional students who could successfully argue that 5mm aluminium would absorb all the beta radiation and because there is still a count rate there must be gamma radiation.



(b) Explain which radiations were emitted from the source.

(3)

When paper is placed there is no significant drop in count rate. so there is no α radiation. when a aluminium sheet of 1mm thick is placed, count rate drops significantly so there is β radiation. when a aluminium sheet of 5mm is placed, the count rate is higher than count rate of lead sheet so γ radiation is present. β radiation can penetrate ~~aluminium of 1mm~~ paper. γ radiation can penetrate aluminium.

ResultsPlus
Examiner Comments

A rare example of a response that scored full marks.

Since a piece of paper ~~can~~ cannot reduce the count, the source does not emit alpha radiation.
Aluminium sheet of thickness 1mm can reduce the count. so the source emits β radiation.
Lead sheet of thickness 5mm can reduce the count. so the source emits γ radiation.

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Examiner Comments

The first sentence of this response scores the 1st mark, and the second sentence scores the 2nd mark. However there is no comparison between the effect on the count rate of the 5 mm aluminium and the 5mm lead and therefore the 3rd mark is not awarded.

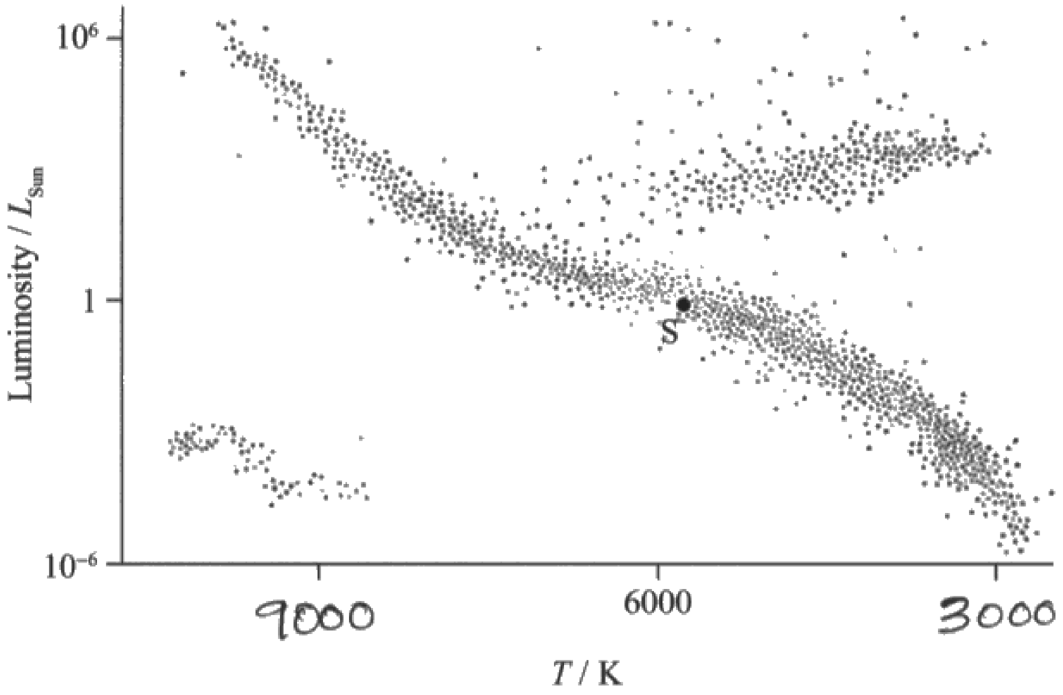
~~α~~ α-radiations have been emitted as the count reduces ~~for~~ ~~absorbtion~~ ~~fo~~ from air to paper. β-radiations also been emitted as the count drops when an aluminium sheet is been used as the absorber. γ-radiations are also been emitted as there is a change in ~~the~~ count when a lead sheet is ~~used~~ used.

ResultsPlus
Examiner Comments

This student does not realise that the apparent reduction in the count rate when the paper absorber is used is not significant. The comments about aluminium and lead have insufficient detail and are only of GCSE standard.

Question 13 (a)

Most responses showed a good knowledge of how the temperature scale on a Hertzsprung-Russell diagram works. The scale is a reverse scale with temperatures increasing towards the left and is logarithmic. It was not essential to work out a truly logarithmic scale although many students used numbers that they had seen in previous papers that did represent a true log scale: 12 000, 6000 and 3000.

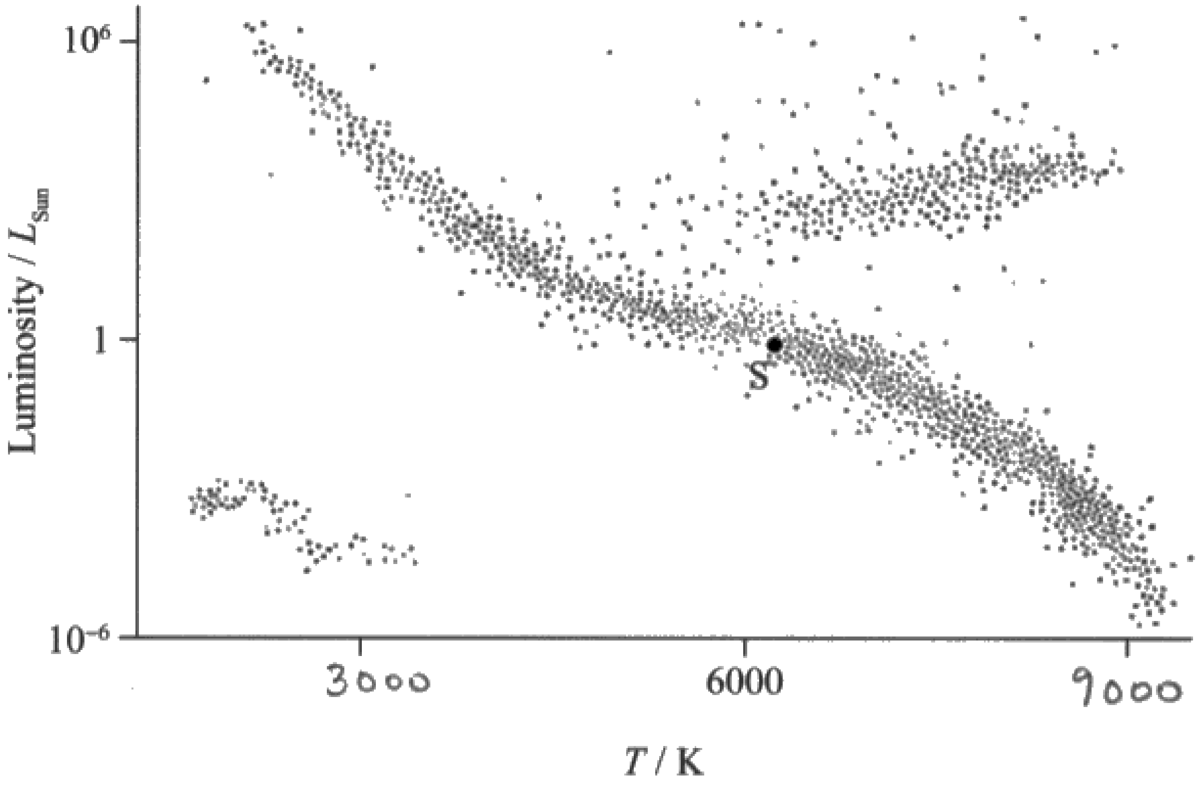


(a) Complete the temperature scale on the Hertzsprung-Russell diagram.

(2)

ResultsPlus
Examiner Comments

This response scores the first mark only. The temperature scale is a reverse scale but it is linear.



ResultsPlus Examiner Comments

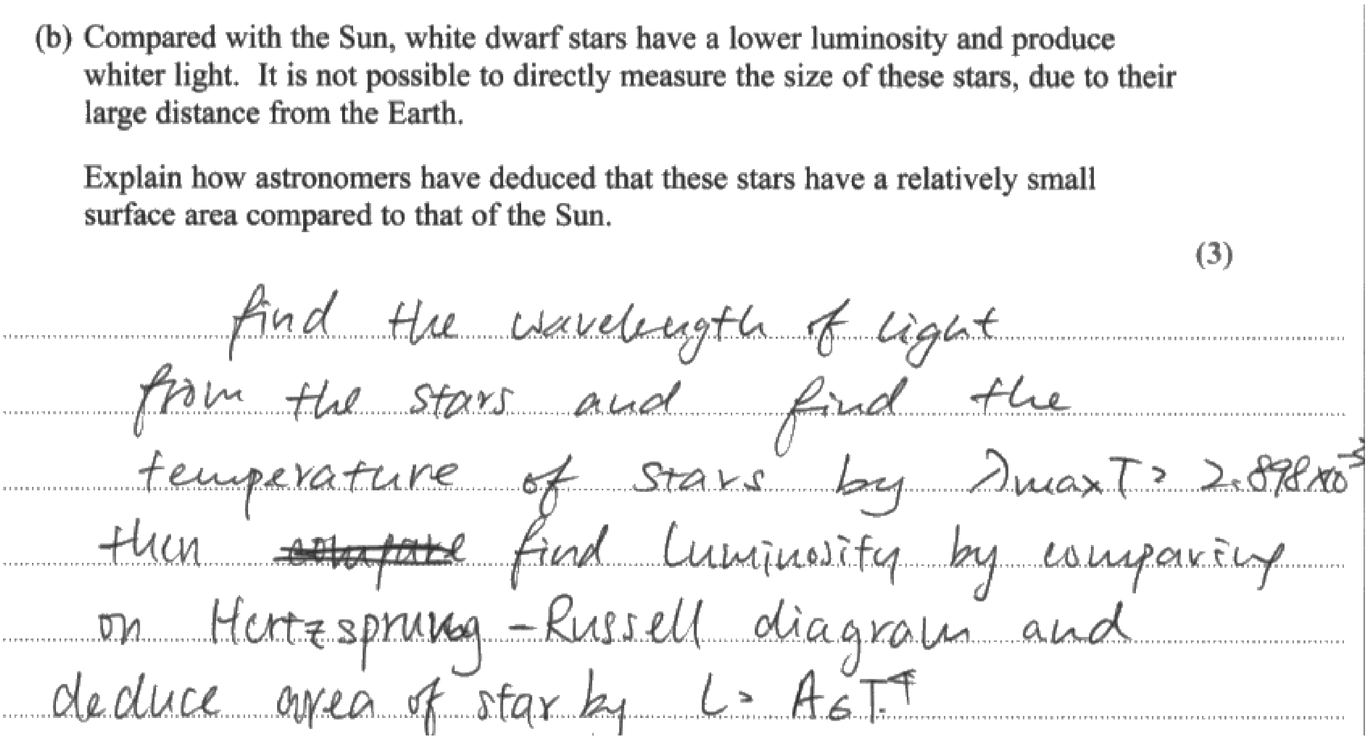
This response scored 0. The scale is not reversed and is also linear.

Question 13 (b)

What students tried to do in many cases was to make use of memorised mark schemes from questions set in previous series as the basis for their response. This was generally unsuccessful. Students must read the question carefully and frame a response that takes the context of the question into account. In this case the context required students to consider how astronomers were able to draw a particular conclusion, and many of the responses seen did not address this.

The initial sentence in the question gives information about the luminosity of white dwarfs compared with the Sun and that white dwarfs emit whiter light than the Sun. At this level students should know that stars behave as black bodies and emit a spectrum of wavelengths with a peak known as λ_{max}. For the first two marks students were expected to identify that whiter light means that the peak of this spectrum is closer to the blue end of the spectrum and hence that λ_{max} for the white dwarf stars will be less than for the Sun. A comparison with the Sun is also required for the second mark. To score the third mark it was necessary to link the Stefan-Boltzmann equation with the given low luminosity to conclude that the surface area would be small for these stars.

Making use of the Hertzsprung-Russell diagram does not provide an explanation for this deduction of the astronomers because the H-R diagram is just a plot of known stars. However students who were able to say that the H-R diagram shows that white dwarf stars have a higher temperature than the Sun and could then make suitable use of the Stefan-Boltzmann equation could score a maximum of 2 marks.



(b) Compared with the Sun, white dwarf stars have a lower luminosity and produce whiter light. It is not possible to directly measure the size of these stars, due to their large distance from the Earth.

Explain how astronomers have deduced that these stars have a relatively small surface area compared to that of the Sun.

(3)

find the wavelength of light from the stars and find the temperature of stars by $\lambda_{max}T = 2.898 \times 10^{-3}$ then ~~compare~~ find luminosity by comparing on Hertzsprung-Russell diagram and deduce area of star by $L = A\sigma T^4$

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Examiner Comments

This response is an example of the many that seemed to be answering a different question, trying to make use of a mark scheme for a previous question on a similar topic. No attempt has been made to make a comparison with the Sun and there is no reference to the information given about the white dwarf stars in the first sentence of the question. It scores no marks.

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Examiner Tip

Always read the whole question thoroughly before deciding how best to answer it.

The white dwarf stars were found to have higher temperatures than the Sun from the H-R diagram. According to Stefan-Boltzmann's law, $L = \sigma A T^4$, $A \propto \frac{L}{T^4}$ where L is the luminosity, T is temperature in kelvin and A is the surface area of the star and σ is the stefan Boltzmann constant. Since they have lower luminosity than sun, and ~~as~~ Area $\propto \frac{\text{Luminosity}}{\text{Temperature}}$, they would have much smaller surface area than the sun. ~~Surface Area = $4\pi r^2$. This means that the radius is small and hence~~

(Total for Question 13 = 5 marks)

ResultsPlus
Examiner Comments

In this response the H-R diagram has been used to identify that the white dwarf stars have higher temperature than the Sun, and describes fully how the Stefan-Boltzmann equation can be used. This scores max 2 using the alternative mark scheme.

According to $L = A\sigma T^4$, since white dwarf starts have lower luminosities [illegible] and ~~light~~ higher temperature, their surface area (A) must be relatively smaller than that of the Sun.

Since they produce whiter light, their frequency would be higher, results in a lower λ_{max}. According to $\lambda_{max} \cdot T = 2.898 \times 10^{-3}$ mK, they must have a higher temperature.

(Total for Question 13 = 5 marks)

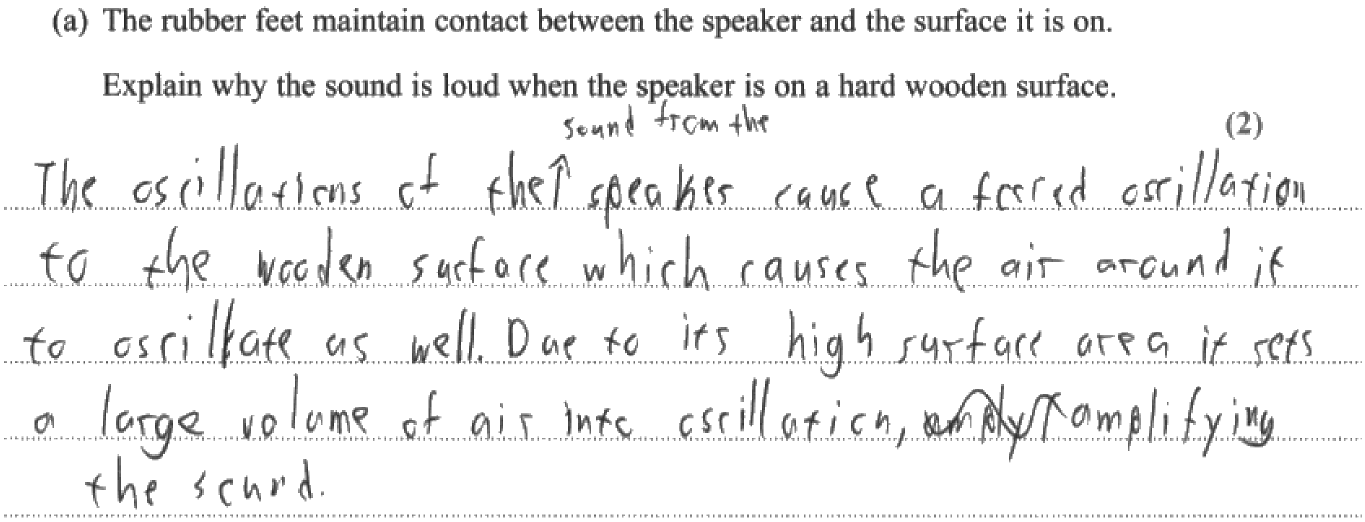
ResultsPlus
Examiner Comments

This is an example of a response that scores all 3 marks.

The first four lines score the 3rd mark. The final three lines score the 1st and 2nd marks. The comparison with the Sun is clear.

Question 14 (a)

Many responses suggested that students had latched onto the word 'loud' in the question and gave their answer in terms of resonance, thus anticipating part (b). Others thought that the rubber feet would cause damping and somehow this would make the sound loud. Other incorrect approaches included sound being reflected from the hard wooden surface and sound travelling faster through the wood. Those who thought that this was an example of resonance as well as those with a better understanding of the context were often able to describe how the surface was forced to oscillate and so scored the 1st mark. It was unusual to find a response where the student realised that the vibrating surface would make the air in contact with it also vibrate and that this is what would make the sound loud.



(a) The rubber feet maintain contact between the speaker and the surface it is on.

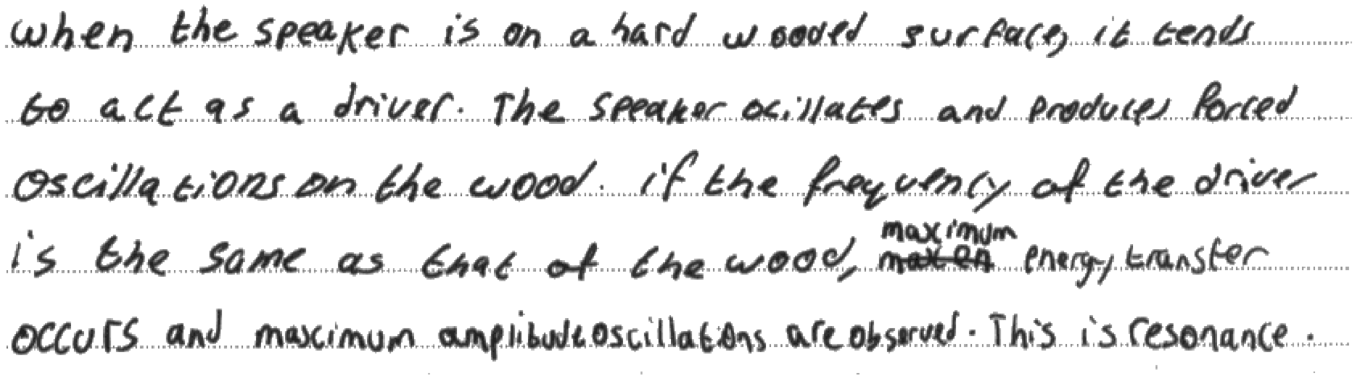
Explain why the sound is loud when the speaker is on a hard wooden surface.

(2)

The oscillations of the sound from the speaker cause a forced oscillation to the wooden surface which causes the air around it to oscillate as well. Due to its high surface area it sets a large volume of air into oscillation, ~~amply~~ amplifying the sound.

ResultsPlus
Examiner Comments

This student scores both marks for this clear answer.



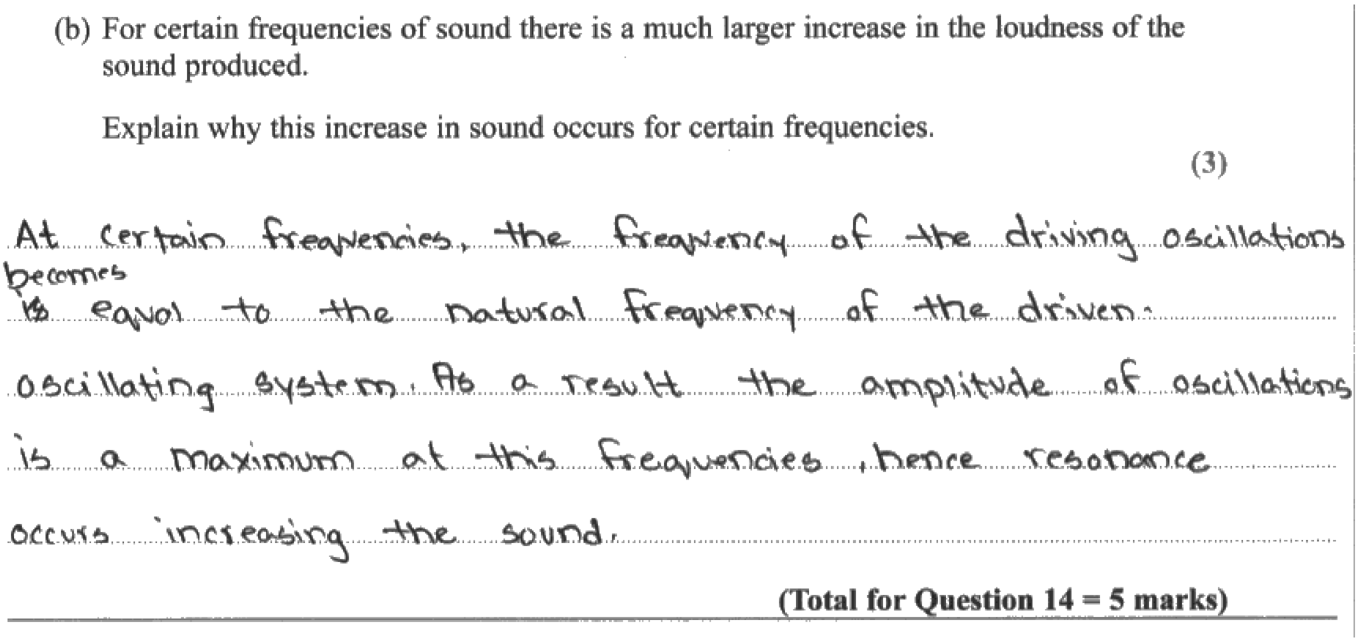
when the speaker is on a hard wooded surface, it tends to act as a driver. The speaker oscillates and produces forced oscillations on the wood. if the frequency of the driver is the same as that of the wood, ~~maxen~~ maximum energy transfer occurs and maximum amplitude oscillations are observed. This is resonance.

ResultsPlus
Examiner Comments

A response typical of many. The idea of the surface being driven into oscillation by the speaker scores the 1st mark. However, this student thinks that the effect is due to resonance and does not go on to score the 2nd mark.

Question 14 (b)

While most students realised that this situation was an example of resonance, many proceeded to give a completely general description not taking the context into account at all. This meant that only the 2nd and 3rd marks were available. For the 1st mark it was necessary to identify that it was the wooden surface that was being forced to oscillate and that it was the natural frequency of the wooden surface that was important.



(b) For certain frequencies of sound there is a much larger increase in the loudness of the sound produced.

Explain why this increase in sound occurs for certain frequencies.

(3)

At certain frequencies, the frequency of the driving oscillations ~~is~~ becomes equal to the natural frequency of the driven. oscillating system. As a result the amplitude of oscillations is a maximum at this frequencies, hence resonance occurs increasing the sound.

(Total for Question 14 = 5 marks)

ResultsPlus
Examiner Comments

This response is typical of those who gave a general description of resonance scoring the 2nd and 3rd marks only. The 'driven' referred to in line 2 has not been identified as the wooden surface.

ResultsPlus
Examiner Tip

Learn definitions thoroughly but always try to adapt a general description to the context of the question.

- If the frequencies = Fo the natural frequency of oscillation; then resonance will occur.
- This is an increase in Amplitude due to the driving force having an equal frequency to Fo.

ResultsPlus
Examiner Comments

This response only scores the 3rd mark for resonance. An increase in amplitude is insufficent, a maximum amplitude would be necessary to score the 2nd mark.

- when the wood surface is forced to oscillate on or near to it's natural frequency resonance occurs.
- There is maximum energy transfer from speaker to the wooden surface and hence amplitude of oscillation is large
- This results to a large sound output

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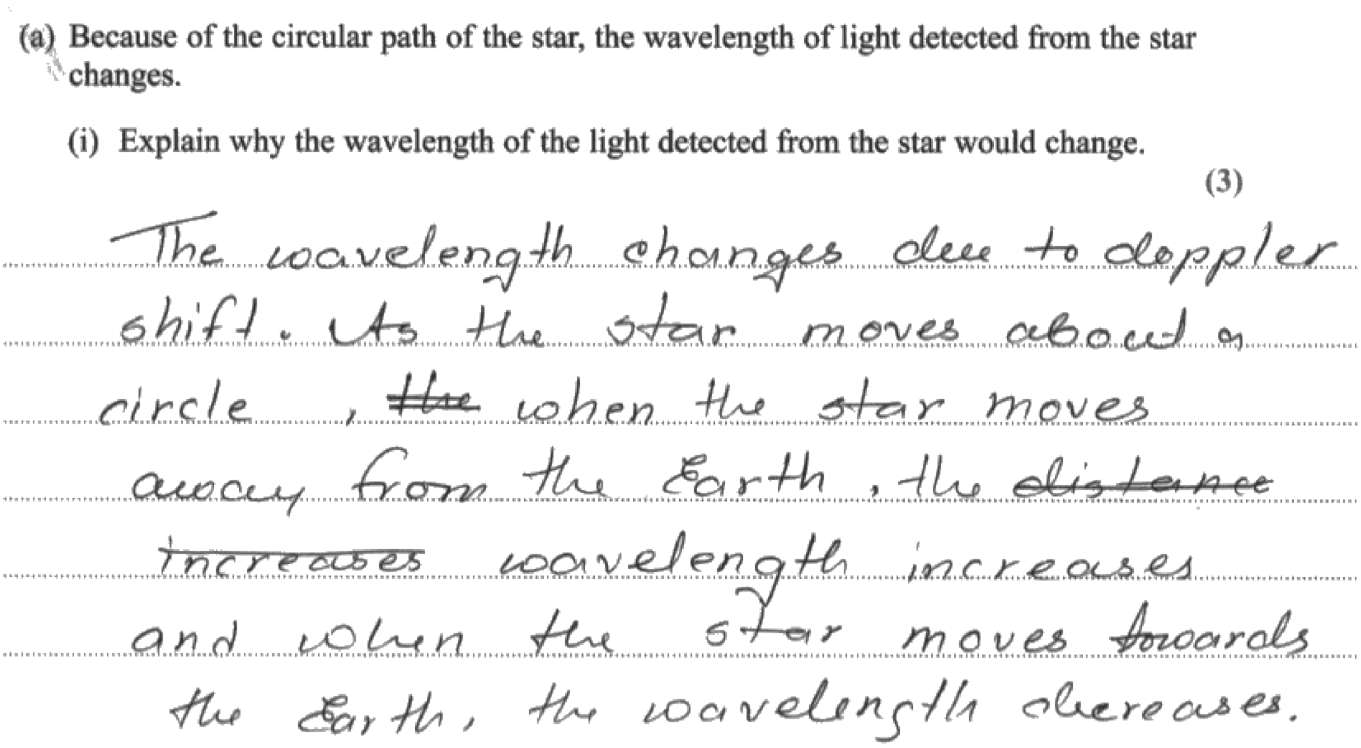
Examiner Comments

An excellent answer scoring all three marks.

Question 15 (a) (i)

Although most students realised that the question was about Doppler shift thus scoring the 1st mark, many of them could not correctly relate this to the context of the question, an exoplanet orbiting a star. Many answers were seen where the Doppler shift observer was thought to be on the exoplanet or in some case on the star, rather than on Earth. It was also clear that a few students have misunderstood the effect, thinking that it relates to distance from the observer rather than relative velocity between source and observer.



(a) Because of the circular path of the star, the wavelength of light detected from the star changes.

(i) Explain why the wavelength of the light detected from the star would change.

(3)

The wavelength changes due to doppler shift. As the star moves about a circle , ~~the~~ when the star moves away from the Earth , the ~~distance increases~~ wavelength increases and when the star moves towards the Earth, the wavelength decreases.

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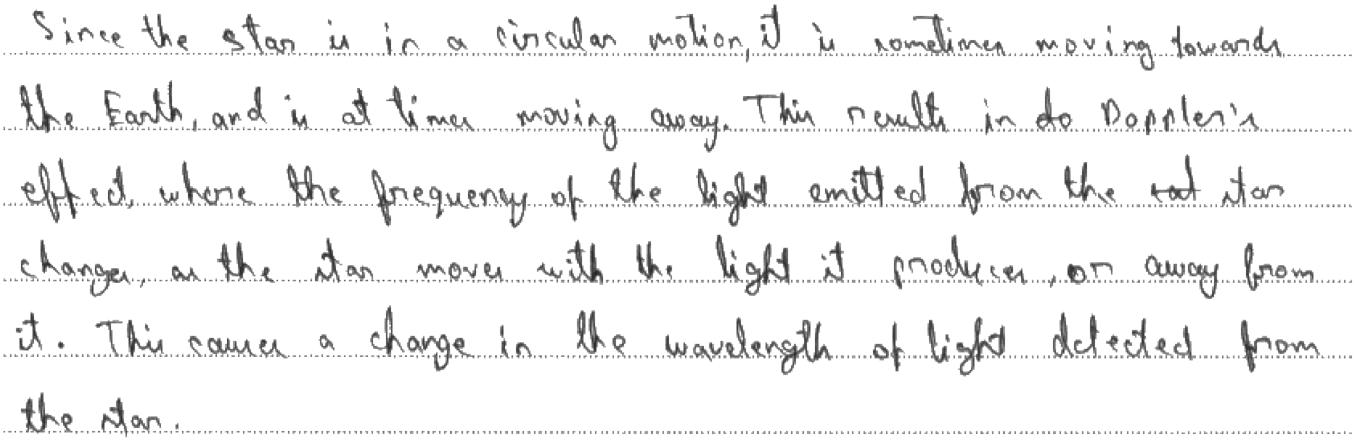
Examiner Comments

This response is well set out and has the correct physics for all three marks clearly presented.



Since the star is in a circular motion, it is sometimes moving towards the Earth, and is at times moving away. This results in ~~do~~ Doppler's effect, where the frequency of the light emitted from the ~~rat~~ star changes, as the star moves with the light it produces, or away from it. This causes a change in the wavelength of light detected from the star.

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Examiner Comments

This response has identified that the star is moving towards and away from the Earth and has named the effect. Although they have said that the wavelength changes as a result they have not said what the change is and so do not score the 3rd mark.

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Examiner Tip

The question is about wavelength and so there is little point discussing the frequency of the light emitted from the star.

Because of the doppler effect. when the exoplanelt moves toward the stationary star it is known as blue shift and when it moves away from the star it is known as redshift hence the wavelength changes.

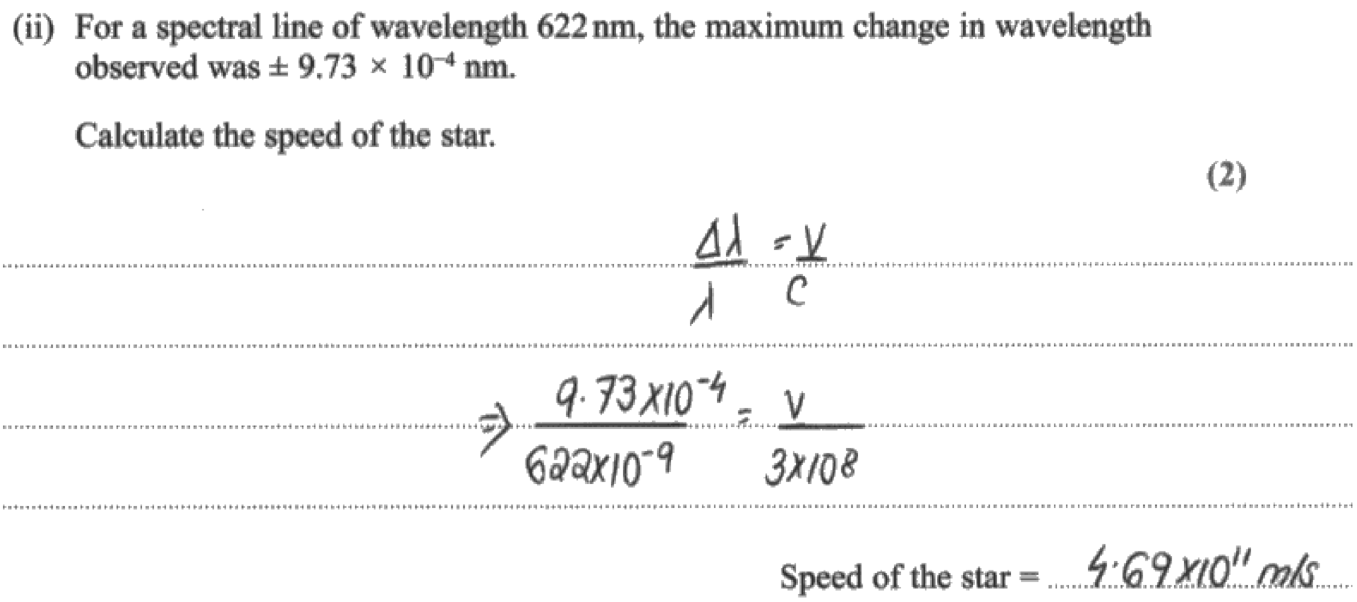
ResultsPlus
Examiner Comments

The effect has been identified as the Doppler effect but it is incorrectly thought to be due to the relative motion of the star and exoplanet. Only the 1st mark is scored.

Question 15 (a) (ii)

The majority of students were successful with this calculation.

Some who possibly did not understand that the wavelength received on Earth from this star would sometimes be greater and sometimes less than the emitted wavelength, were confused by the maximum change in wavelength being given as a ± value. There were also errors with the powers of 10, usually by those who did not realise that both numerator and denominator are in nanometres and so a conversion to metres is not necessary.



(ii) For a spectral line of wavelength 622 nm, the maximum change in wavelength observed was ± 9.73 × 10^{-4} nm.

Calculate the speed of the star.

(2)

$$\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$$

$$\Rightarrow \frac{9.73 \times 10^{-4}}{622 \times 10^{-9}} = \frac{v}{3 \times 10^{8}}$$

Speed of the star = 4.69×10^{11} m/s

ResultsPlus
Examiner Comments

The equation has been used correctly, but this student has changed the units of Δλ into metres but left the unit of λ in nanometres leading to an incorrect power of 10 in the answer.

ResultsPlus
Examiner Tip

Make sure that all units of length are the same.

$\frac{v}{c} = \frac{\Delta\lambda}{\lambda}$ $\Delta\lambda = 622.000973 - 621.999027$

$= 1.946 \times 10^{-3}$

$\Rightarrow \frac{v}{3\times10^{8}} = \frac{1.946\times10^{-3}}{622}$ $\therefore v = 938.5\ ms^{-1}$

Speed of the star = $938.5\ ms^{-1}$

ResultsPlus
Examiner Comments

This student has added Δλ to λ, then subtracted it and finally found the difference between them before substituting into the equation. Effectively this means that they have used twice the given value of Δλ and so their answer is twice the correct value. The first mark has been awarded.

$\frac{622nm - 9.73\times10^{-4}nm}{622nm} = \frac{v}{c\ 3\times10^{8})}$ | $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$

$v = 2.99\times10^{6} m/s$

$v = 3\times10^{6} m/s$

Speed of the star = $3\times10^{6} m/s$

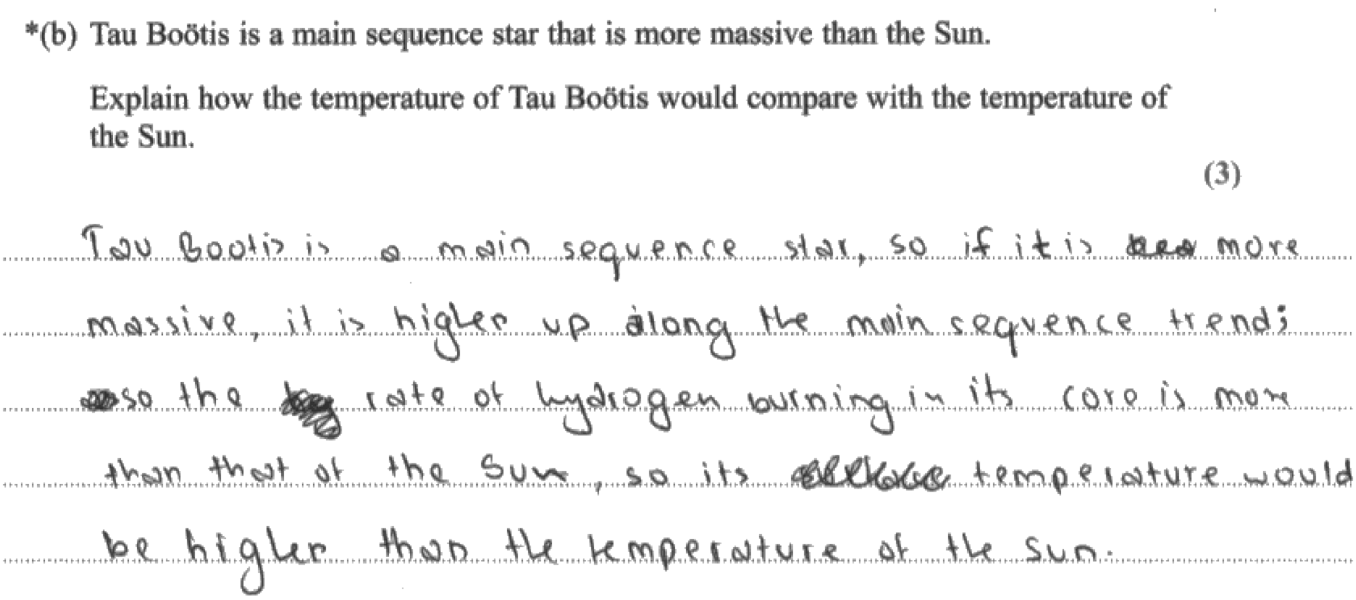
ResultsPlus
Examiner Comments

In this answer the numerator on the left hand side of the equation should be the change in wavelength, however the student has substituted a wavelength, not a change in wavelength. Neither mark can be awarded.

Question 15 (b)

Many students realised that there are larger gravitational forces in a more massive star and that this would lead to a temperature larger than the Sun, thus scoring the 1st and 3rd marks. Whilst many also could identify that there would be a greater rate of fusion in the more massive star, they did not add that this greater rate of fusion is in the core of the star and so did not score the 2nd mark.

The Hertzsprung-Russell diagram is a plot of known stars and as such cannot provide an explanation of why the temperature of a more massive star is higher than the Sun. However, those who could use their knowledge of the H-R diagram to identify that a more massive main sequence star would be higher up the main sequence than the Sun and hence have a higher temperature could score a maximum of two marks on the alternative mark scheme.



***(b)** **Tau Boötis is a main sequence star that is more massive than the Sun.**

Explain how the temperature of Tau Boötis would compare with the temperature of the Sun.

(3)

Tau Bootis is a main sequence star, so if it is more massive, it is higher up along the main sequence trend; so the rate of hydrogen burning in its core is more than that of the Sun, so its temperature would be higher than the temperature of the Sun.

ResultsPlus
Examiner Comments

This response scores 2 marks using either of the mark schemes. In this context, we accept a greater rate of hydrogen burning in the core of the star as being equivalent to a greater rate of fusion in the core of the star. There is no mention of the greater gravitational forces in the star so the 1st mark is not scored.

According to, $L = \sigma T^4 A$, more massive means greater ~~Su~~ surface area, since L is constant, ~~at main sequence~~ ~~The su~~ the surface ~~tem~~ temperature of Tau Boötis must be less than Sun.

ResultsPlus
Examiner Comments

It was a common error to try to use the Stefan-Boltzmann equation to answer this question, as is seen in this response. Whilst it may be true that a more massive star will have a greater surface area than the Sun it is not true that all main sequence stars have the same luminosity. This scores no marks.

Question 15 (c)

Most students realised that the change in wavelength would be small but were not able to use appropriate physics to justify this and so scored no marks.

(2)

For a less massive ~~star~~ exoplanet, the gravitational forces between the star and the exoplanet will be less. So the point around which the star revolves will be closer to the star as a result the shift in wavelength detected will be less.

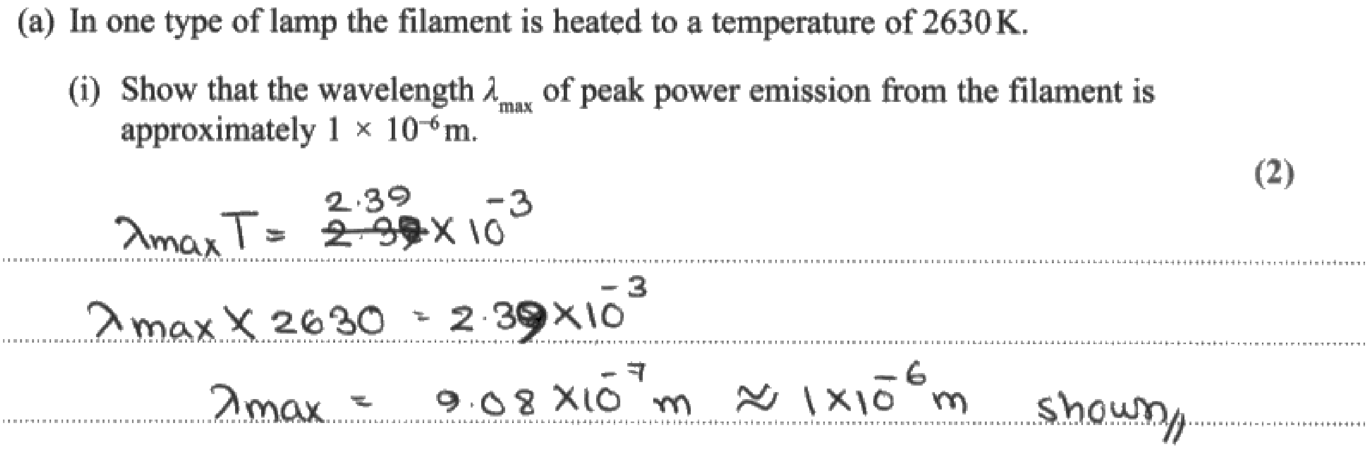
(Total for Question 15 = 10 marks)

ResultsPlus
Examiner Comments

This student shows excellent understanding of the context and has included all the points in the mark scheme.

Question 16 (a) (i)

This question required the use of Wien's law to find the wavelength of peak power emission from the filament and was completed successfully by most. It was pleasing that very few students failed to give their answer to at least one more significant figure than the 'show that' value given in the question.



(a) In one type of lamp the filament is heated to a temperature of 2630 K.

(i) Show that the wavelength λ_{max} of peak power emission from the filament is approximately 1×10^{-6} m.

(2)

$\lambda_{max} T = \overset{2.39}{\cancel{2.39}} \times 10^{-3}$

$\lambda_{max} \times 2630 = 2.39 \times 10^{-3}$

$\lambda_{max} = 9.08 \times 10^{-7}$ m $\approx 1 \times 10^{-6}$ m shown//

ResultsPlus
Examiner Comments

This student has not used the Wien's Law equation correctly. Possibly the student has tried to learn the equation not realising that it is given at the back of the question paper. The value of the constant is incorrect and so the answer scores no marks.

ResultsPlus
Examiner Tip

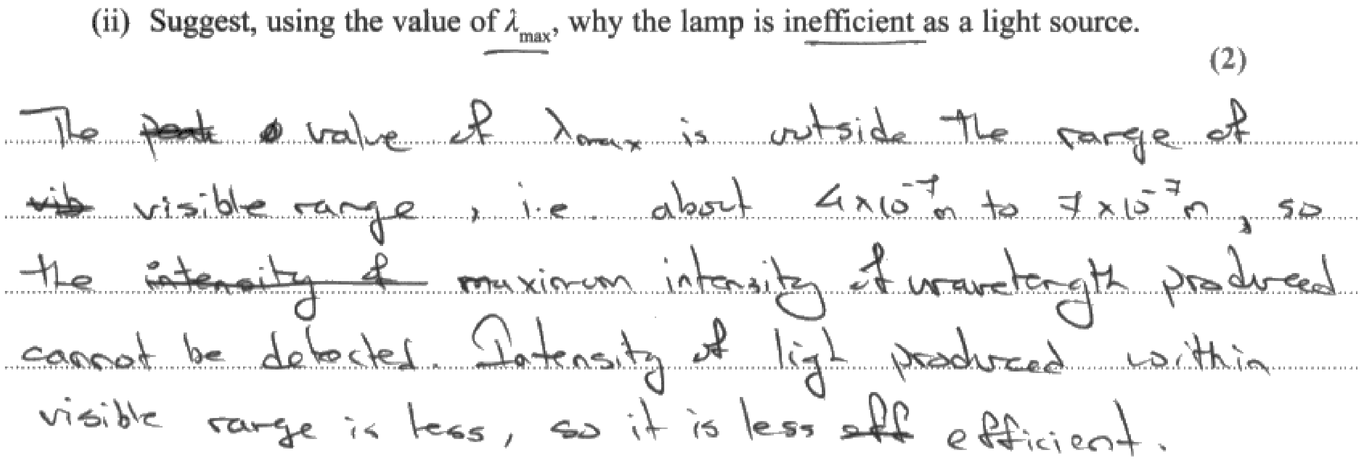
Make sure that you are very familiar with the data and equations given at the back of every question paper. Always check that you have remembered equations and the value of constants correctly before use.

Question 16 (a) (ii)

It was unusual to see responses that scored both marks, underlining that many students have only a tenuous grasp of black-body radiation and the meaning of λ_{max} .

Many students knew something about the topic but their answers were usually too vague to score either mark. Some realised that λ_{max} is outside the visible range but did not specifically say that it is in the infra-red range or that it is longer than visible light.

Very few made a clear statement that could score the 2nd mark, with many thinking that no visible light is emitted. We saw quite a number of responses where it was stated that λ_{max} is too small to be visible and therefore the lamp is inefficient.



(ii) Suggest, using the value of λ_{max}, why the lamp is inefficient as a light source.

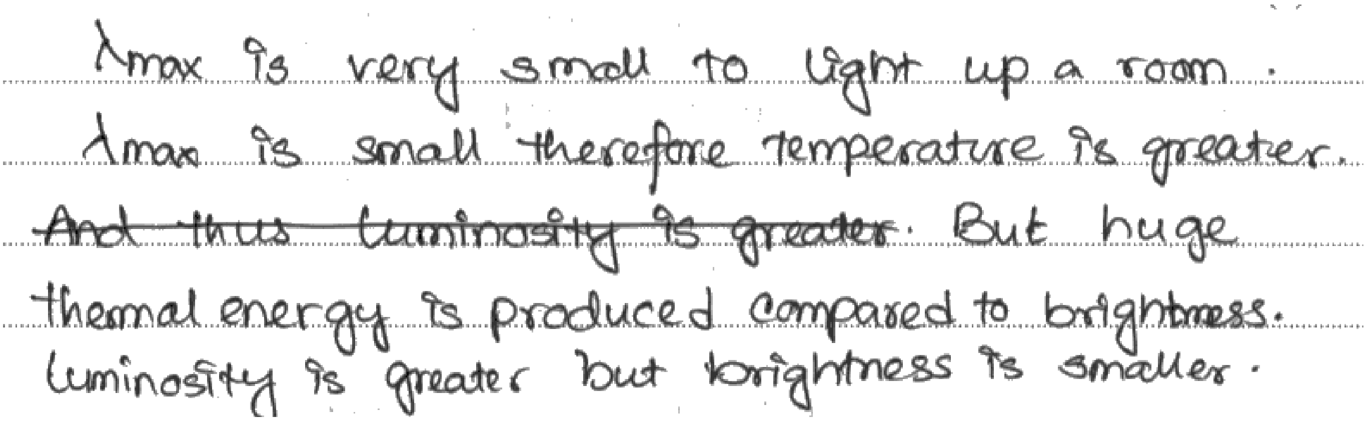
(2)

The ~~peak~~ value of λ_{max} is outside the range of ~~vis~~ visible range, i.e. about 4×10^{-7} m to 7×10^{-7} m, so the ~~intensity of~~ maximum intensity of wavelength produced cannot be detected. Intensity of light produced within visible range is less, so it is less ~~eff~~ efficient.

ResultsPlus

Examiner Comments

This response does not score the 1st mark because although they know what the range of visible wavelengths is, they have not identified that the value of λ_{max} is longer than the longest wavelength of visible light. Their final sentence just about has the idea that only some of the radiation produced by the lamp is visible and so scores the 2nd mark.



λmax is very small to light up a room. λmax is small therefore temperature is greater. ~~And thus luminosity is greater.~~ But huge thermal energy is produced compared to brightness. luminosity is greater but brightness is smaller.

ResultsPlus
Examiner Comments

This shows the kind of muddled thinking seen in answers to this question. This student seems to have pulled together unrelated statements showing a lack of understanding of several physics concepts as well as physics terminology.

Question 16 (a) (iii)

This calculation was generally successfully done. The most usual mistakes involved issues with converting temperatures to kelvin.

$pV = NkT$.

when V, N is constant,

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$\Rightarrow \frac{P_1}{438} = \frac{58.5 \times 1000}{291}$$

$$\Rightarrow P_1 = \frac{58.5 \times 1000 \times 438}{291} = 88051.5 \text{ Pa}$$

$= 88.1 \text{ kpa}$

Temperature,

$273 + 18 = 291$ K

$273 + 165 = 438$ K.

Pressure of gas = 88.1 kpa.

ResultsPlus
Examiner Comments

A clearly set out answer showing all stages of working scoring all 3 marks.

$$\frac{P_1 \cancel{V_1}}{T_1} = \frac{P_2 \cancel{V_2}}{T_2} \qquad \frac{P_1}{T_1} = \frac{P_2}{T_2}$$

$$P_2 = \frac{P_1 \times T_2}{T_1}$$

$$= \frac{58.5\times10^3 \times (273+18)}{(165+273)}$$

$= 38866\,Pa$ ~~$\approx 38.9kPa$~~ $\approx 38.9kPa$

Pressure of gas = 38.9kPa

ResultsPlus
Examiner Comments

This student has remembered the relationship between pressure and temperature and has shown correctly how to convert the Celsius temperature to kelvin. However the two temperatures have been muddled up and substituted the wrong way round leading to an incorrect answer. The first 2 marks are scored.

$PV = NKT$ | N and V and K constat

$\therefore \frac{P_1}{T_1} = \frac{P_2}{T_2} \Rightarrow P_2 = \frac{58.5\times10^3}{18} \times 165$

$= 536.25 \times 10^3$ Pa

Pressure of gas = 536 kPa

ResultsPlus
Examiner Comments

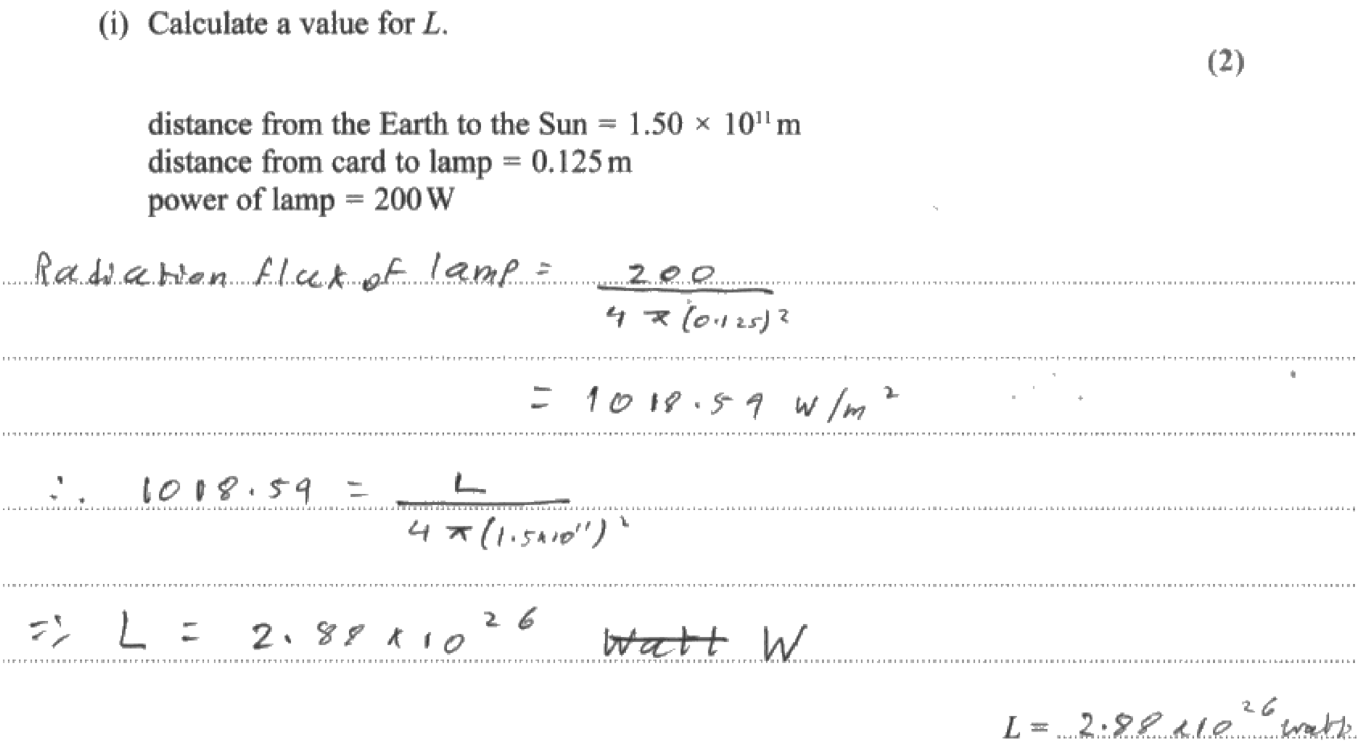
In this answer Celsius temperatures have been used instead of kelvin. The 1st mark only is scored.

ResultsPlus
Examiner Tip

Remember that in all calculations involving temperature, except when using the specific heat capacity equation, it is essential to convert Celsius temperatures to kelvin by adding 273.

Question 16 (b) (i)

Most students realised that the equation they needed to use was the one relating the radiant energy flux to luminosity and distance, but not all realised that the radiant energy flux due to the Sun would equal that due to the lamp. Another problem for many was relating the terminology usually used for astronomical bodies to the lamp. These students did not appreciate that luminosity is a power and so the 200W given as the power of the lamp is the luminosity of the lamp.



(i) Calculate a value for L.

(2)

distance from the Earth to the Sun = 1.50×10^{11} m
distance from card to lamp = 0.125 m
power of lamp = 200 W

Radiation flux of lamp = $\frac{200}{4\pi(0.125)^2}$

$= 1018.59 \text{ W/m}^2$

$\therefore 1018.59 = \frac{L}{4\pi(1.5\times10^{11})^2}$

$\Rightarrow L = 2.88 \times 10^{26}$ ~~Watt~~ W

$L = 2.88 \times 10^{26}$ watts

ResultsPlus
Examiner Comments

This response shows the calculation done in two stages, first calculating the value of the radiant energy flux for the lamp, then using that value as the radiant energy flux for the Sun. This is an acceptable method with the correct answer and the correct unit therefore scoring both marks.

$\cancel{L} \cancel{=} \quad \cancel{\frac{L_S}{L_L}} \cancel{=} \cancel{D} \quad \frac{L_{sun}}{L_{lamp}} = \frac{d^2_{sun}}{d^2_{lamp}}$

$\frac{L}{200} = \frac{(1.5 \times 10^{11})^2}{(0.125)^2}$

$L = 2.88 \times 10^{26}$ W

$L =$ 2.88×10^{26} W

ResultsPlus
Examiner Comments

This example shows how the calculation can be done in one stage by using understanding of the inverse square law and applying it to this situation. By using ratios this student has done some work in their head equating expressions for *F* and cancelling 4π. This response scores both marks.

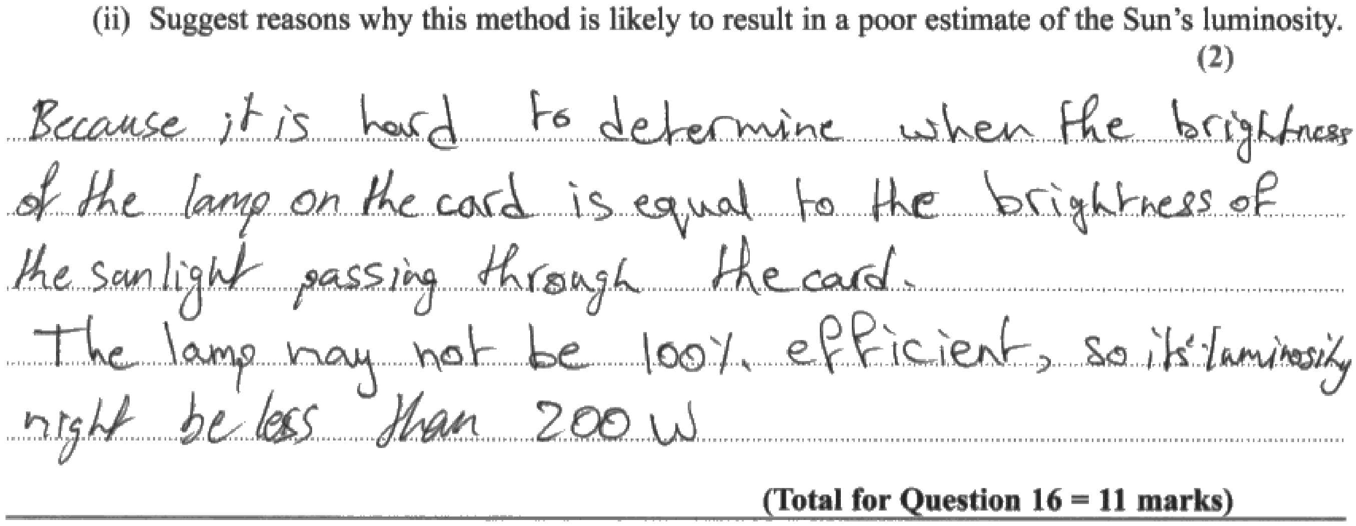
$F = \frac{L}{4\pi d^2} = \frac{200}{4\pi (0.125)^2}$

ResultsPlus
Examiner Comments

Provided the response shows one use of the equation with values of both *d* and *L* taken from the question, the 1st mark can be scored. This response shows this clearly, although the student does not know how to proceed.

Question 16 (b) (ii)

From their responses it seemed that many students did not understand the experiment that had been described at the beginning of part (b). This led to answers that made vague references to inefficiency or uncertainties meaning that the 1st and 3rd marks were not commonly awarded. Most of those that cited the inefficiency of the lamp did not express their idea with sufficient detail to score the mark. Many thought that it was the uncertainty in the distance to the Sun that caused the problem, overlooking the much higher percentage uncertainty in the measurement of the small distance from the lamp to the card. The non-creditworthy idea of the lamp-card distance being much less than the card-Sun distance was mentioned quite often. The ideas for the second mark were often seen, but again not always described with sufficient clarity. The most commonly awarded mark was to those who said that some of the Sun's light is absorbed by the atmosphere.



(ii) Suggest reasons why this method is likely to result in a poor estimate of the Sun's luminosity.
(2)

Because it is hard to determine when the brightness of the lamp on the card is equal to the brightness of the sunlight passing through the card.
The lamp may not be 100% efficient, so it's luminosity might be less than 200 W

(Total for Question 16 = 11 marks)

ResultsPlus
Examiner Comments

This is a clearly set out answer scoring the first and second marks.

ResultsPlus
Examiner Tip

When asked to 'suggest', give as much detail as you can; try not to give vague answers.

Question 17 (a) (i)

Although almost all responses showed some idea of what the binding energy of a nucleus is, most did not give a sufficiently precise definition to score the mark. It was necessary to identify the constituents of a nucleus as either nucleons or protons and neutrons. It was common to see responses that muddled nuclei and nucleons.

(a) (i) State what is meant by the binding energy of a nucleus.

(1)

When a nucleus splits into its component nuclei, energy is released which is called binding energy.

ResultsPlus
Examiner Comments

This response shows the common mistake of muddling nuclei with nucleons. Possibly the student is confusing this definition with one for nuclear fission.

ResultsPlus
Examiner Tip

This is a definition that should be learned.

The energy used to hold the nucleus together. It corresponds to the strong nuclear force.

ResultsPlus
Examiner Comments

This shows the common misconception of the meaning of binding energy.

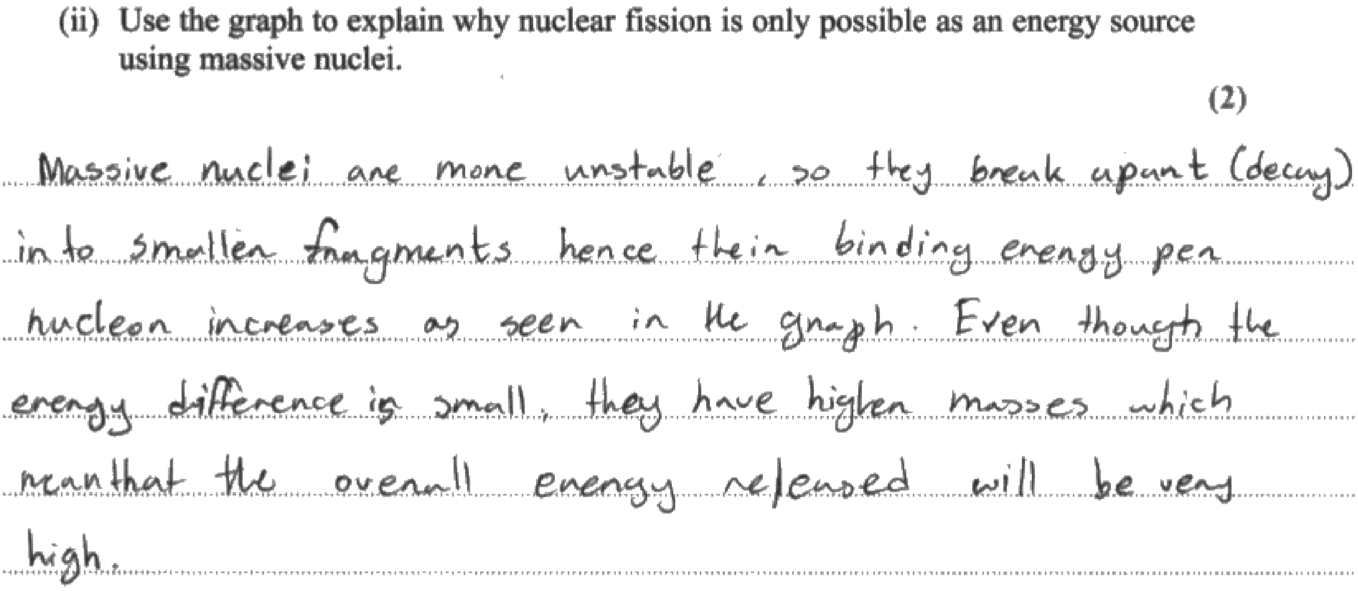
Question 17 (a) (ii)

It is essential at this level that students are used to using the term 'massive' in a physics context;in other words, that massive means having a large mass, not necessarily being large.Conversely it is not acceptable to refer to 'smaller' nuclei instead of 'lighter' or 'less massive' nuclei.This error could be overlooked when applying the 1st mark because of the way the question is worded but is not acceptable for the 2nd mark.

It is surprising that when directed to 'use the graph', which has a clearly labelled y-axis 'binding energy per nucleon', there were quite a lot of responses where reference was made to the binding energy rather than the binding energy per nucleon.

The way the question has been worded requires students to also consider what happens with less massive nuclei and why this means that fission of these nuclei does not provide an energy source. It was rare to see this attempted and so, rare to be able to award the 2nd mark.

A number of students seemed to try to use a mark scheme they had memorised from a question from a previous paper which sometimes enabled the first mark to be scored.



(ii) **Use the graph to explain why nuclear fission is only possible as an energy source using massive nuclei.**

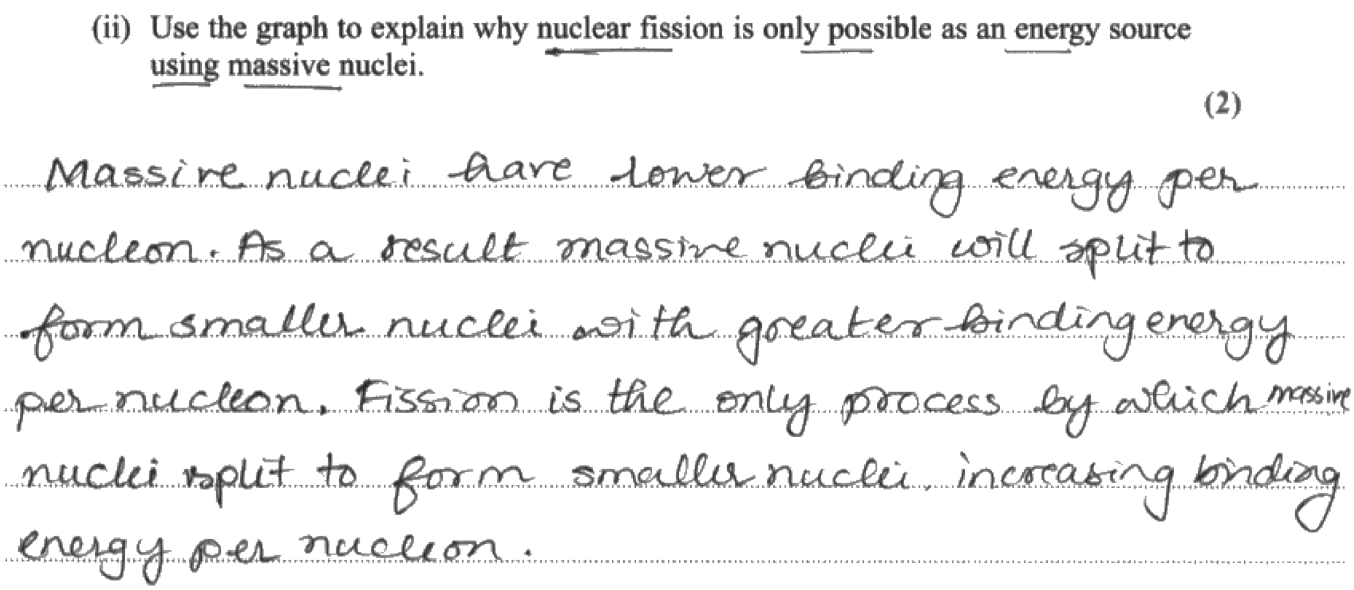
(2)

Massive nuclei are more unstable, so they break apart (decay) into smaller fragments hence their binding energy per nucleon increases as seen in the graph. Even though the energy difference is small, they have higher masses which mean that the overall energy released will be very high.

ResultsPlus

Examiner Comments

The first sentence in this response has most of what is required for the 1st mark. The second sentence looks like a misremembered mark scheme for a different question where it was important to identify that there were many nucleons and so although the energy preleased per nucleon was small there were many of them and so the total energy was large. However in that sentence they have included that energy is released and put together with their first sentence can just qualify for the 1st mark.



(ii) Use the graph to explain why nuclear fission is only possible as an energy source using massive nuclei.

(2)

Massive nuclei have lower binding energy per nucleon. As a result massive nuclei will split to form smaller nuclei with greater binding energy per nucleon. Fission is the only process by which massive nuclei split to form smaller nuclei, increasing binding energy per nucleon.

ResultsPlus
Examiner Comments

This student has correctly stated that for a massive nucleus the binding energy per nucleon will increase as a result of fission, but they have not said that this results in the release of energy and so score no marks. This was a common omission.

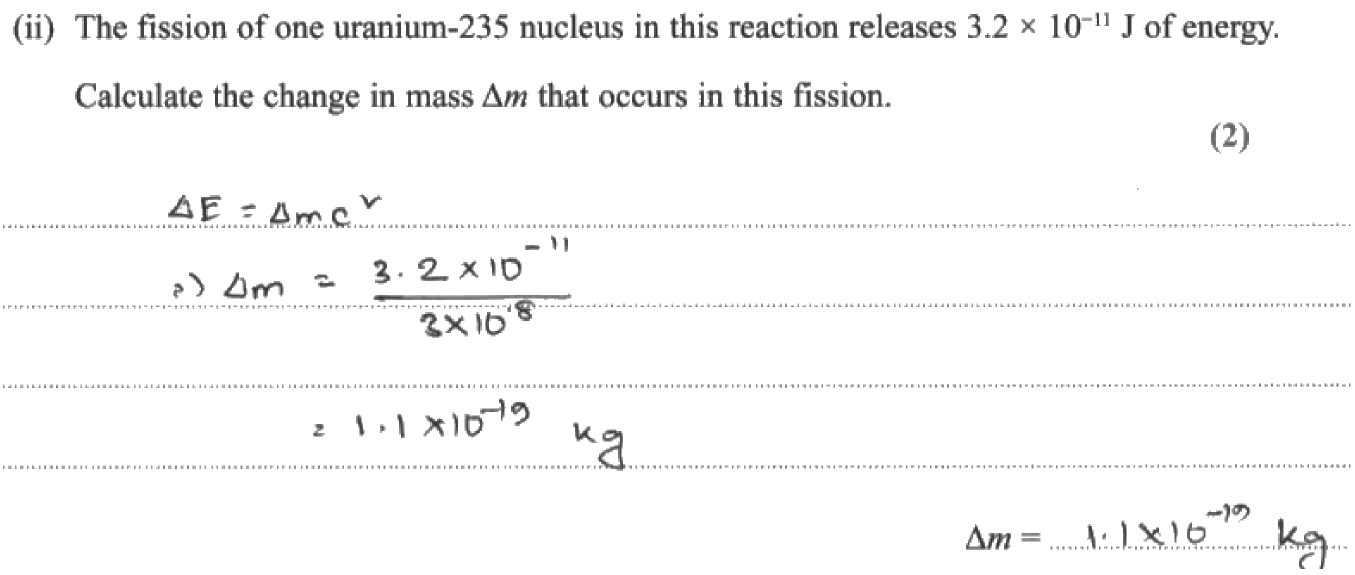
Question 17 (b) (i)

It is expected that students will have met nuclear equations like this one, summarising a fission reaction. While most could calculate the proton number of the ruthenium nucleus, it was surprising how many could not correctly work out the nucleon number of the cadmium nucleus. Some failed to take the neutron on the left hand side of the equation into account, getting 121; others seemed not to notice that there are three neutrons on the right hand side, getting 124. A variety of other numbers were also seen.

Question 17 (b) (ii)

Most students realised that this calculation is very straightforward and just requires the substitution of the given energy and the speed of light into $\Delta E = c^2 \Delta m$, and were able to reach the correct value for Δm with its unit, kg. There were the usual few responses where the correct equation was quoted but when the substitution was done, the value of the speed of light was not squared.

There were a small number of students who changed the given energy from joules to electronvolts then gave the value of Δm as 200 MeV/c^2. This is an acceptable alternative approach and scored both marks.



(ii) The fission of one uranium-235 nucleus in this reaction releases 3.2×10^{-11} J of energy.

Calculate the change in mass Δm that occurs in this fission.

(2)

$\Delta E = \Delta m c^{v}$

$\Rightarrow \Delta m = \dfrac{3.2 \times 10^{-11}}{3 \times 10^{8}}$

$= 1.1 \times 10^{-19}$ kg

$\Delta m =$ 1.1×10^{-19} kg

ResultsPlus
Examiner Comments

Although the correct equation has been quoted, the substitution does not show that the value of the speed of light is squared. The first mark cannot be given and the answer is incorrect.

ResultsPlus
Examiner Tip

Always check when substituting that any necessary powers are included.

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

$\Rightarrow \Delta m = \frac{3.2 \times 10^{-11}}{(3 \times 10^{8})^2}$

$= 3.5 \times 10^{-28}$ kg

$\Delta m =$ 3.5×10^{-28} kg

ResultsPlus
Examiner Comments

There is a rounding error in this answer. The calculation comes to 3.5555 x 10^{-28} kg. The digit 5 is recurring.

When rounded to 2 significant figures as this student has done, the correct value is 3.6 x 10^{-28} kg. Only the 1st mark is scored.

man $= \frac{3.2 \times 10^{-11}}{1.6 \times 10^{-19}} = 200$ MeV/c^2

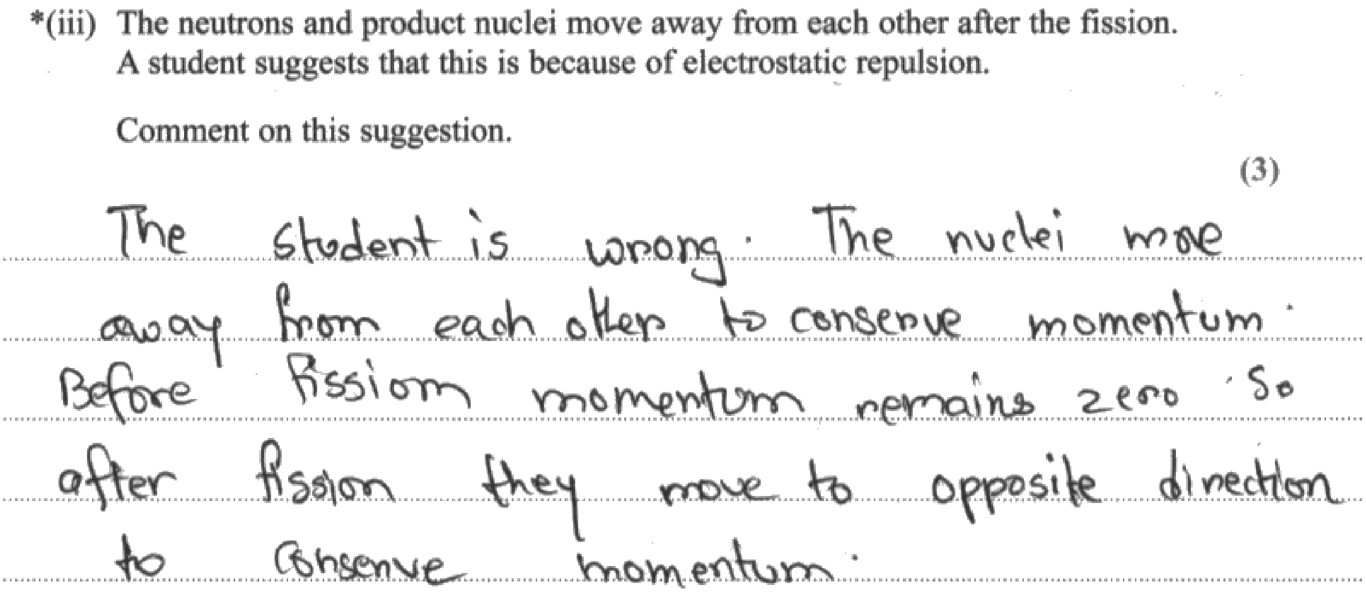
$\Delta m =$ 200 MeV/c^2

ResultsPlus
Examiner Comments

This shows how the calculation may be done with a final unit of MeV/c^2 instead of kg.

Question 17 (b) (iii)

In order to address the question it is necessary to comment on both why electrostatic repulsion is not the reason for the neutrons and the nuclei to move away from each other, and also what is likely to cause this to happen. Often marks were lost because both these aspects were not tackled.



*(iii) The neutrons and product nuclei move away from each other after the fission.
A student suggests that this is because of electrostatic repulsion.

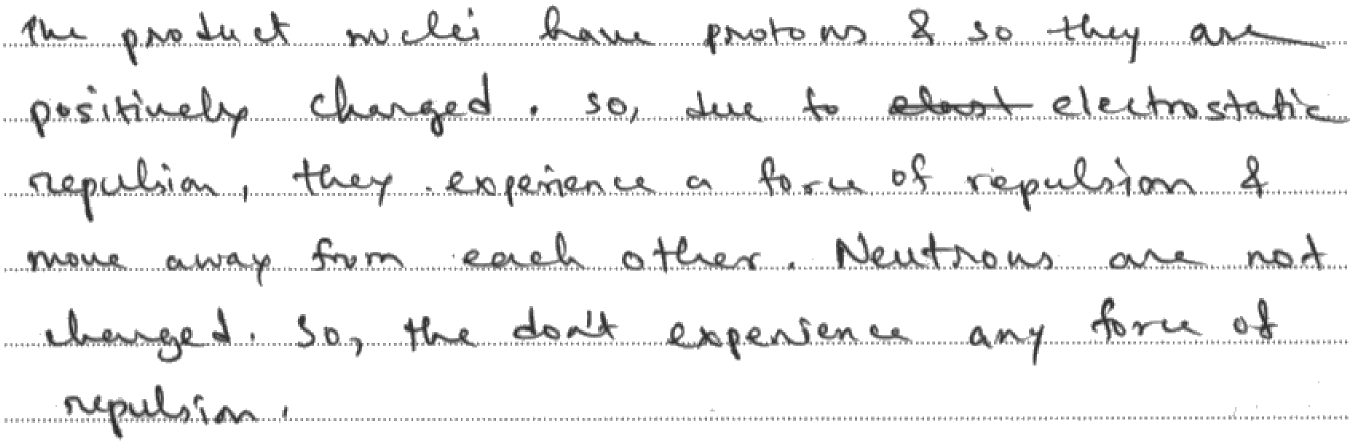
Comment on this suggestion.

(3)

The student is wrong. The nuclei moe away from each other to conserve momentum. Before Fission momentum remains zero. So after fission they move to opposite direction to conserve momentum.

ResultsPlus
Examiner Comments

This response has given us the reason why the neutrons and the product nuclei move away from each other but has not explained why the suggestion that it is because of elecrostatic repulsion is wrong. It scores the 2nd and 3rd marks.



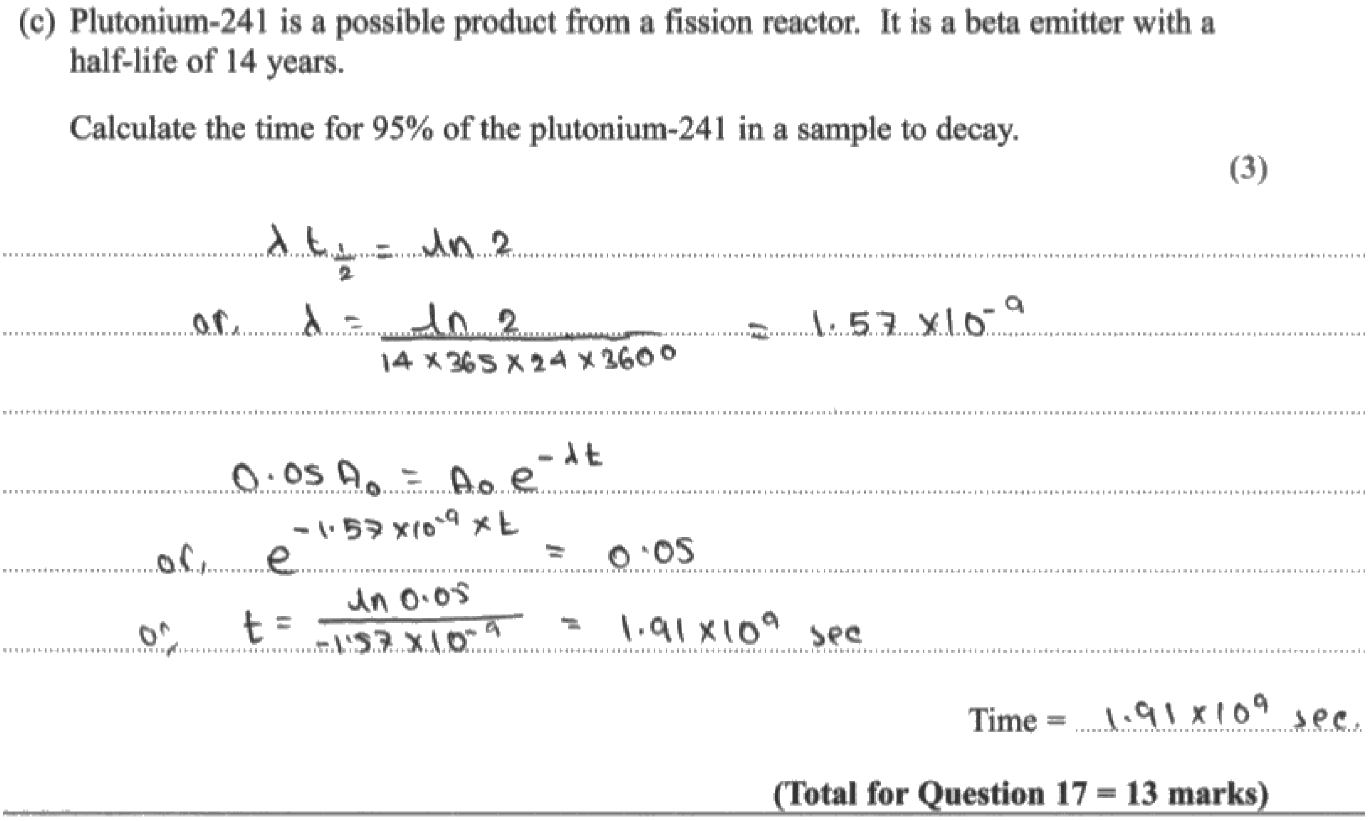
the product nuclei have protons & so they are positively charged. so, due to ~~elect~~ electrostatic repulsion, they experience a force of repulsion & move away from each other. Neutrons are not charged. So, the don't experience any force of repulsion.

ResultsPlus
Examiner Comments

This is a very full explanation of why the student's suggestion cannot be correct but does not attempt to explain why the neutrons and product nuclei might move away from each other. This means that only the 1st mark can be awarded.

Question 17 (c)

This calculation was generally well done with all but the weakest students scoring at least the 1st mark. The most common error was to calculate the time until 95% of the plutonium remained instead of the time until 95% had decayed. Possibly these students do not fully understand the significance of the N and N_0 in the exponential equation and need more practice in its use. There were some creative ways seen of dealing with the percentage; picking a value for N_0 then calculating the time until the value reduced to 0.05 of their chosen value. This is an acceptable approach and will give the correct answer because N_0 cancels.



(c) Plutonium-241 is a possible product from a fission reactor. It is a beta emitter with a half-life of 14 years.

Calculate the time for 95% of the plutonium-241 in a sample to decay.

(3)

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

or, $\lambda = \frac{\ln 2}{14 \times 365 \times 24 \times 3600} = 1.57 \times 10^{-9}$

$0.05 A_0 = A_0 e^{-\lambda t}$

or, $e^{-1.57 \times 10^{-9} \times t} = 0.05$

or, $t = \frac{\ln 0.05}{-1.57 \times 10^{-9}} = 1.91 \times 10^{9}$ sec

Time = 1.91×10^{9} sec.

(Total for Question 17 = 13 marks)

ResultsPlus
Examiner Comments

This student has done the calculation correctly but made work for themselves by working in seconds, not realising that the whole calculation can be done in years.

(3)

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

$= \frac{\ln 2}{14}$

$= 0.0495 \text{ years}^{-1}$

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

$\Rightarrow 0.95 = e^{-\lambda t}$

$\Rightarrow -\lambda t = \ln 0.95$

$\Rightarrow t = \frac{\ln 0.95}{-0.0495}$

$\therefore t = 1.036$ years

Time = 1.036 years

ResultsPlus
Examiner Comments

The calculation of the decay constant has been done correctly. They have worked with activity *A* rather than number of nuclei *N* but this is acceptable, however they have the ratio A/A_0 as 0.95 instead of 0.05 and hence their final answer is incorrect. They have calculated the time for 95% to remain not 95% to decay. This scores the first two marks.

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

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

$\frac{\ln 2}{\lambda} = \times\frac{14}{1}$

$\lambda = \frac{\ln 2}{14} = 0.0495$

$\ln N = -0.0495 (14)$

$\ln 0.95 N = -0.693$

$0.95 N = e^{-0.693}$

$0.95 N = 0.5$

$N = 0.526$ years

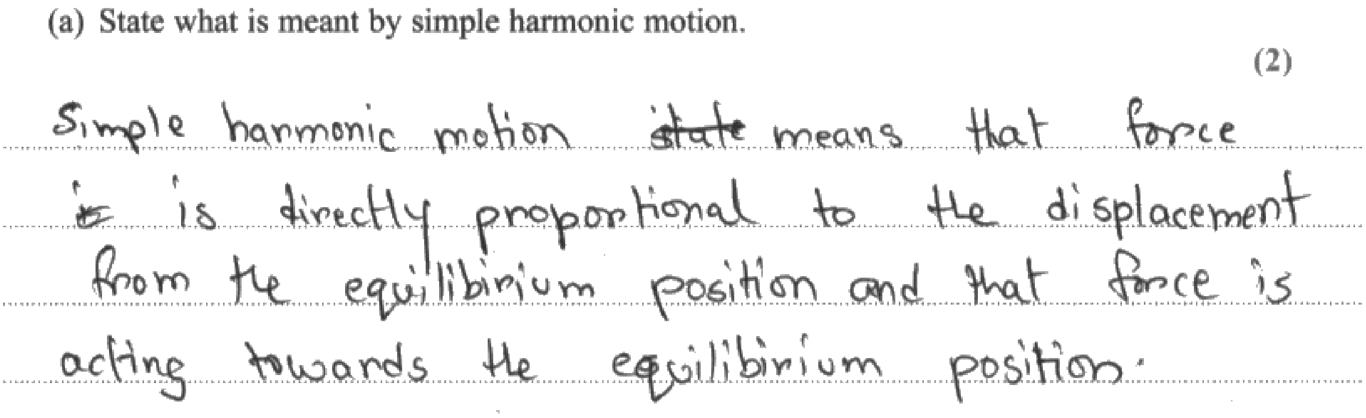
Time = 0.526 years

ResultsPlus
Examiner Comments

This student has used a correct method to find the decay constant and although they seem to know which equation they need to use to find *t* they have not substituted their values into the equation and their attempt to solve it is incorrect. Only the 1st mark is scored.

Question 18 (a)

This is a standard definition, one that has been asked many times before and students should be ready to state this without difficulty. However, it is still common to see just the second mark being awarded. This suggests that an incomplete definition has been learnt. For the first mark it is essential to specify where the displacement is measured from. A statement that "acceleration is proportional to displacement" is only true for simple harmonic motion if the displacement is measured from the equilibrium position. It should be noted that the noun 'equilibrium' is a technical word in physics and it is not the equivalent of 'equilibrium position'.



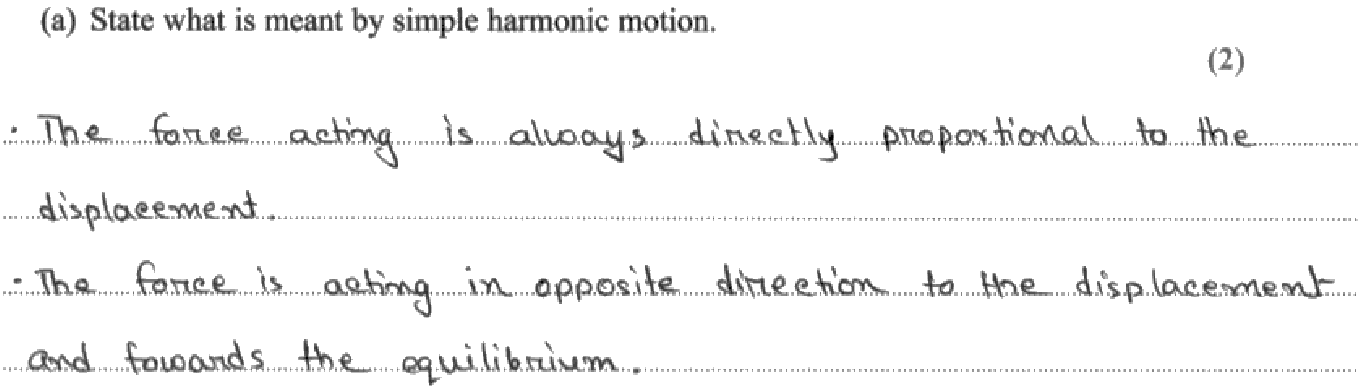
(a) State what is meant by simple harmonic motion.

(2)

Simple harmonic motion ~~state~~ means that force ~~is~~ is directly proportional to the displacement from the equilibrium position and that force is acting towards the equilibrium position.

ResultsPlus
Examiner Comments

This an example of a response that scores both marks.



(a) State what is meant by simple harmonic motion.

(2)

· The force acting is always directly proportional to the displacement.

· The force is acting in opposite direction to the displacement and towards the equilibrium.

ResultsPlus
Examiner Comments

This response does not score the first mark because the reference point for the displacement has not been identified. The first part of the second sentence scores the second mark for the comment that the force is in the opposite direction to the displacement.

The phrase 'towards the equilibrium' does not contribute anything because in physics equilibrium is a state not a position.

ResultsPlus
Examiner Tip

Students should make sure that they learn a full definition of simple harmonic motion.

Question 18 (b)

(i) The calculation was usually successfully completed with occasional instances of forgetting to square the value of ω, or giving the units as rad s^{-1} instead of m s^{-1}. Those who tried to use the full equation for acceleration, $a = -A\,\omega^{2} \cos \omega t$ were usually able to reach the correct answer because they took the value of t as 6 seconds.

There were a few responses that showed that students had remembered a previous exam question where a given distance had to be divided by 2 to find the amplitude, whereas in this question it clearly states that the amplitude is 0.85 m. They used A =0.85/2.

(ii) Many students were less successful with this part of the question. They needed to notice that the *y*-axis of the graph is labelled as the ratio of acceleration to the acceleration due to gravity, then calculate this value using their answer to (i) for the 1st mark. The question asks them to 'show how you have used the graph' which required markings to be made on the graph ideally giving the intersection between a vertical line at 6s and a horizontal line at their value of the ratio *a/g.* They also needed a comment about which region of the graph this represented. A few students who hadn't looked with sufficient care at the graph thought that the labels related to the lines rather than the regions between them.

(b) At one position on a ship, passengers experience a vertical oscillation of amplitude 0.85 m with a period of 6.0 s.

(i) Calculate the maximum acceleration of the passengers.

(3)

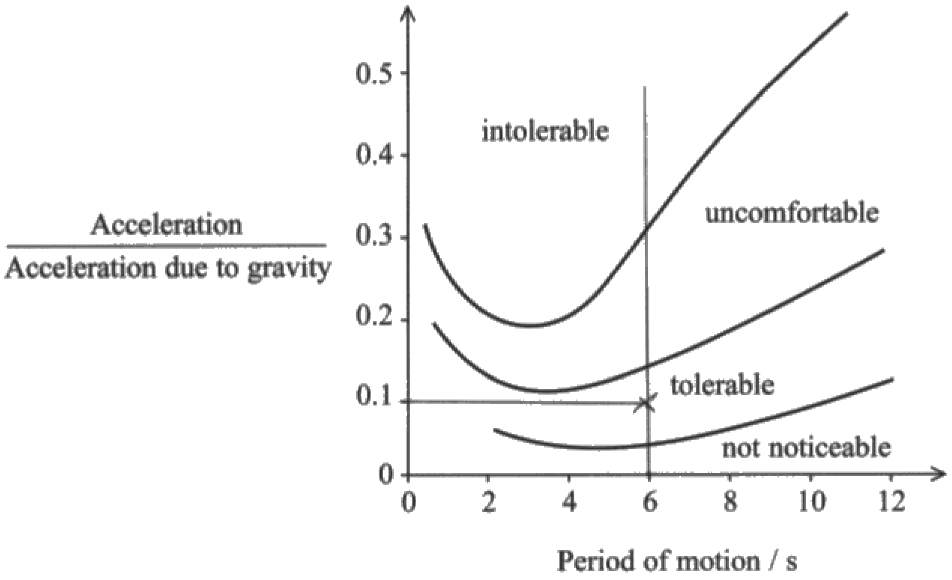
$a = \omega^2 x , x = A$ $\quad$ $a = \omega^2 x$

$\omega = \frac{2\pi}{T}$ $\quad$ $a = \left(\frac{\pi}{3}\right)^2 \times 0.85$

$\omega = \frac{2\pi}{6} = \frac{\pi}{3} / 1.05$ $\quad$ $a = 0.93 ms^{-2}$

Maximum acceleration = $0.93 ms^{-2}$

(ii) Passengers on a ship may suffer from seasickness as the ship rises and falls on the waves. The graph shows the limits of passengers' tolerance to the oscillatory motion.



Determine whether the passengers are likely to feel seasick as a result of the ship's motion.

You should use your value from (b)(i) and show how you have used the graph.

(2)

$\frac{0.93}{9.81} = 0.09 \approx 0.1$

The passengers wouldn't feel sick because the point on the graph is below the graph of tolerable and above not noticeable.

ResultsPlus
Examiner Comments

(i) Calculation correct with unit so scores 3 marks

(ii) The calculation of *a*/*g* has been done and the graph marked to show the point (6, 0.1) as the intersection of vertical and horizontal lines. Although this student thinks that the labels refer to the lines rather than the regions between them, his comment is acceptable because the calculated value of the ratio is a maximum. Both marks are scored.

(b) At one position on a ship, passengers experience a vertical oscillation of amplitude 0.85 m with a period of 6.0 s.

(i) Calculate the maximum acceleration of the passengers.

(3)

$T = \frac{2\pi}{w}$ or, $w = \frac{2\pi}{T} = \frac{2\pi}{6} = \frac{1}{3}\pi = 1.05$

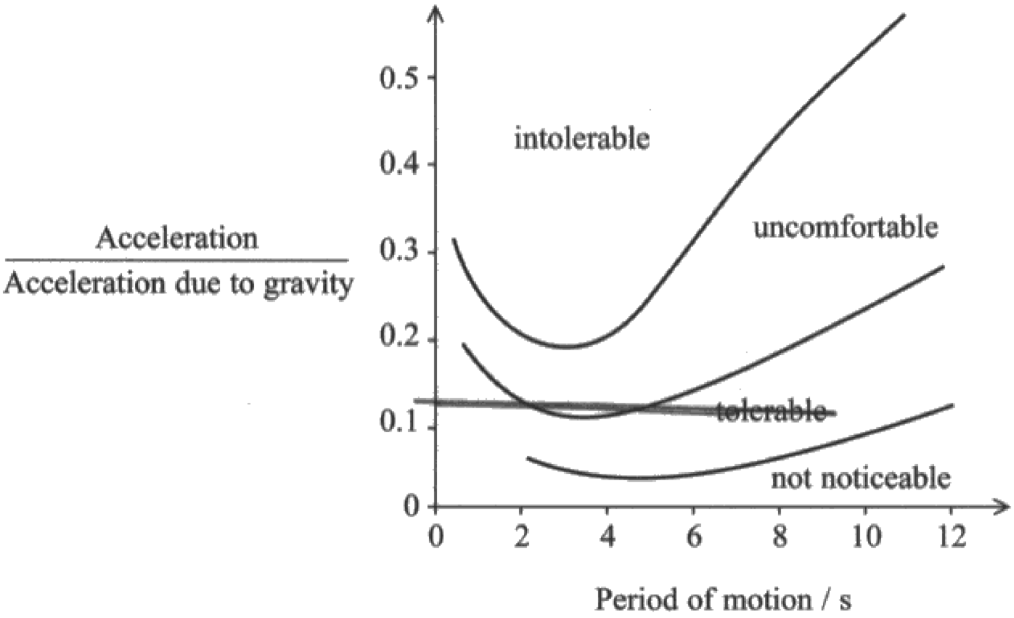
$a = -w^2 x$

so, $a = -(1.05)^2 \times (0.85)$

$= 1.15 \text{ m/s}^2$

Maximum acceleration = 1.15 m/s^2

(ii) Passengers on a ship may suffer from seasickness as the ship rises and falls on the waves. The graph shows the limits of passengers' tolerance to the oscillatory motion.



Determine whether the passengers are likely to feel seasick as a result of the ship's motion.

You should use your value from (b)(i) and show how you have used the graph.

(2)

$$\frac{\text{acceleration}}{\text{acceleration due to gravity}} = \frac{1.15}{9.81} = 0.117$$

The passangers will feel ~~compor~~ comfortable as the acceleration is tolerable as shown in the graph.

ResultsPlus
Examiner Comments

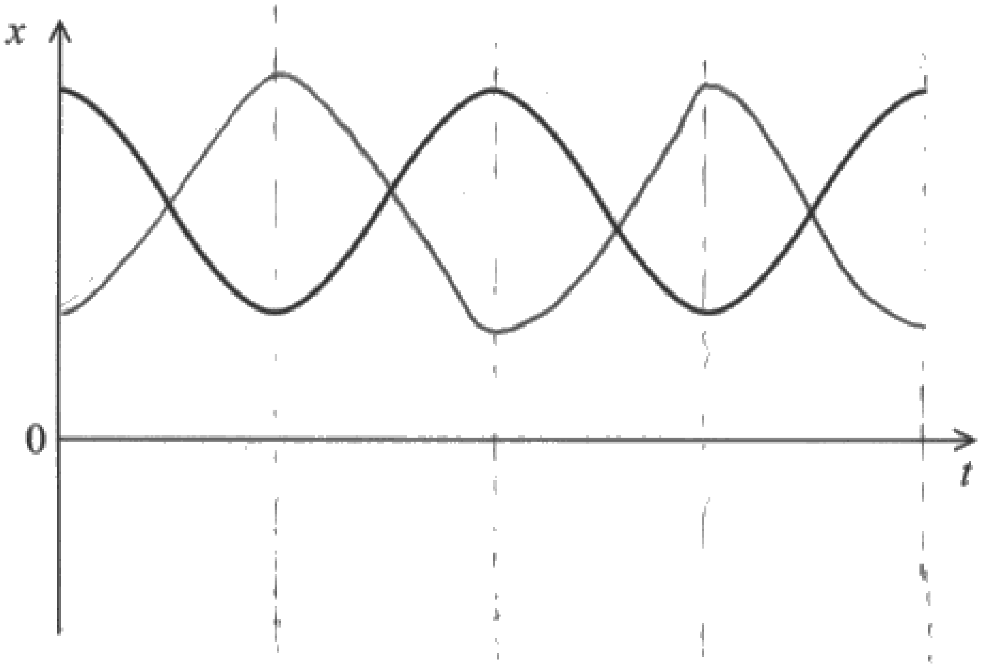
(i) This student has made an arithmetical error in the final calculation and so scores only 2 of the 3 marks.

(ii) The calculation of the ratio using their value from (i) has been done. However they have not realised that they are looking for what happens when the period of the motion is 6 seconds. There is only a horizontal line on their graph and so only the 1st mark is scored.

Question 18 (c)

Most students realised that since the given cosine curve showed how displacement varies with time then the corresponding graph for acceleration would be a minus cosine curve and were able to draw such a curve with the same period as the original, thus scoring the 1st mark. However, only a small minority realised the significance of the given curve not being centred around a zero value of displacement. The displacement plotted has not been measured from the passenger's equilibrium position and so is centred around a positive value of *x.* Since the motion is simple harmonic, acceleration must vary between positive and negative values, and the acceleration curve should be centred around the *x*-axis. Drawing the curve in this position with constant amplitude would score the 2nd mark.

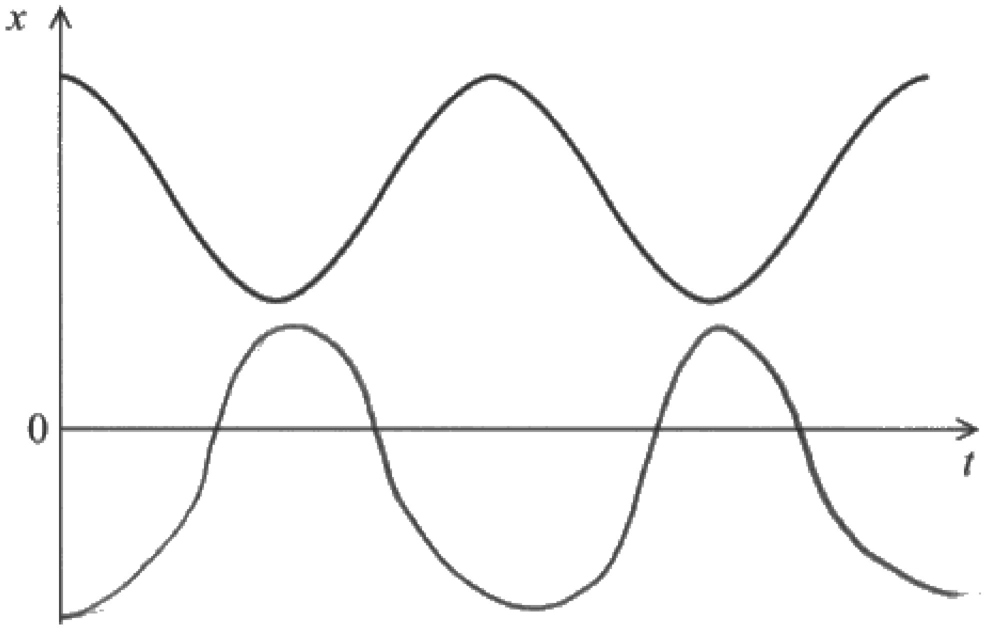
We do not expect perfectly drawn curves but do require students to make a serious effort to make the periods of the two curves match, their curve have constant amplitude and the shape look right.



ResultsPlus
Examiner Comments

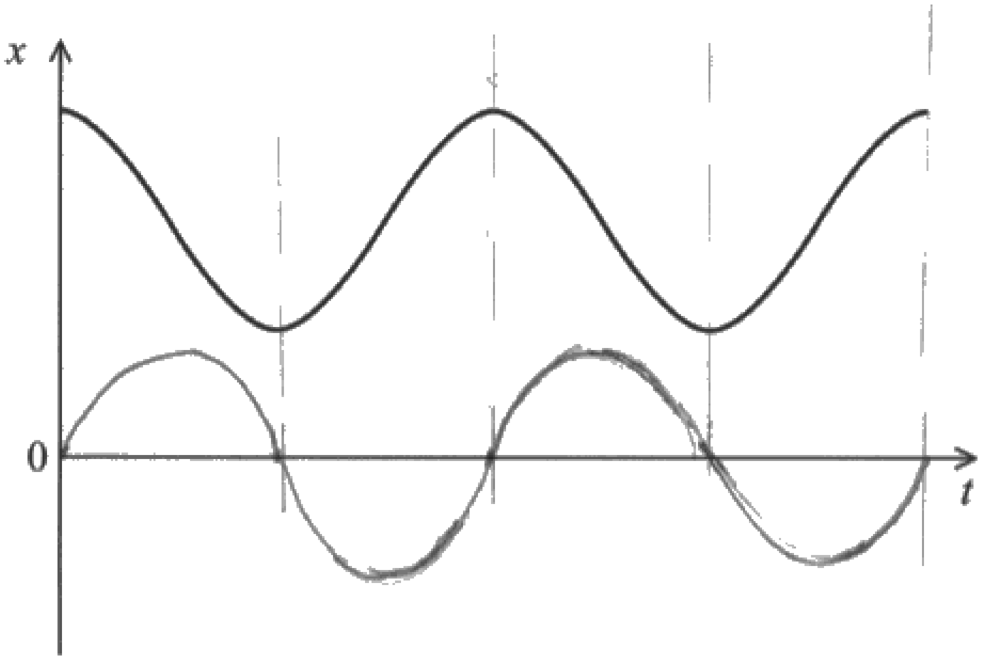
This shows the most common response for this question.

There is a clear attempt to make the period the same as the original and although the curve is not perfect, it is good enough to score the 1st mark.



ResultsPlus
Examiner Comments

This response is close to scoring both marks but the student's curve is not centred about the *x*-axis. It extends further below the axis than it does above and so cannot score the 2nd mark.

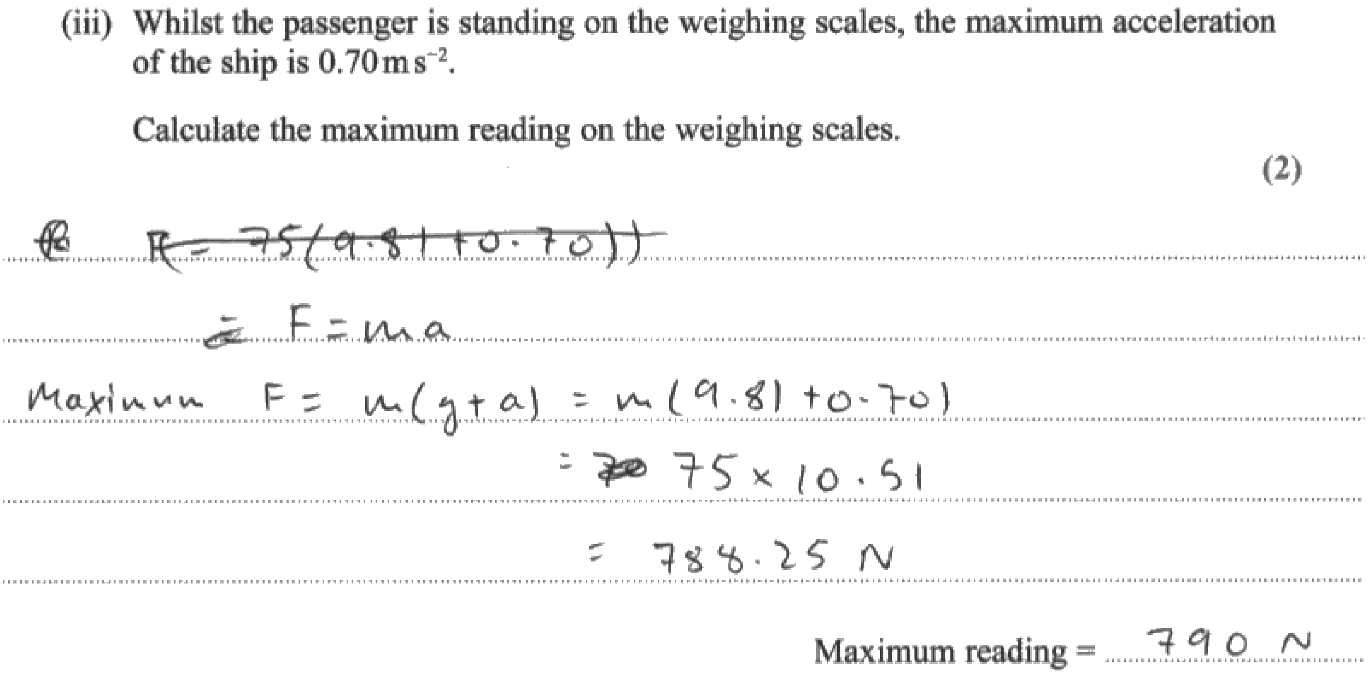


Examiner Comments

This student has worked out that their acceleration curve should be centred around the *x*-axis, but has drawn a positive sine curve. The 2nd mark is scored.

Question 18 (d) (iii)

Almost all students who attempted this question were able to score the 1st mark for substituting values taken from the question into $F = ma$, even if they could go no further. Many were also able to apply their understanding of their free-body diagram to realise that the maximum value for the reaction force would be at the lowest point when $R - mg = ma$. This gives a value of R as 788 N. This was enough for both marks. However, most who got this far then divided by 9.81 N kg^{-1} to change to a value in kg.



(iii) Whilst the passenger is standing on the weighing scales, the maximum acceleration of the ship is $0.70\,\text{m s}^{-2}$.

Calculate the maximum reading on the weighing scales.

(2)

~~R = 75(9.81 + 0.70))~~

F = ma

Maximum F = m(g + a) = m(9.81) + 0.70)

= ~~70~~ 75 × 10.51

= 788.25 N

Maximum reading = 790 N

Examiner Comments

Although it is not completely clear that this student understands what they have done, the calculation is correct and scores both marks.

(2)

$F = ma$

Reaction Force (R) − Weight = ma

~~N=~~ $R = (75 \times 0.70) + (75 \times 9.81) = 788.25\text{N}$

Weighing Scale reading = $\frac{788.25}{9.81} = 80.35\text{kg} = 80.4\text{kg}$

Maximum reading = 80.4 kg

ResultsPlus
Examiner Comments

This is a much more convincing response that also scores both marks.

Weight = Force

Weight = ma

$= 75 \times 0.70$

$= 52.5\text{ N}$

Maximum reading = 52.5 N

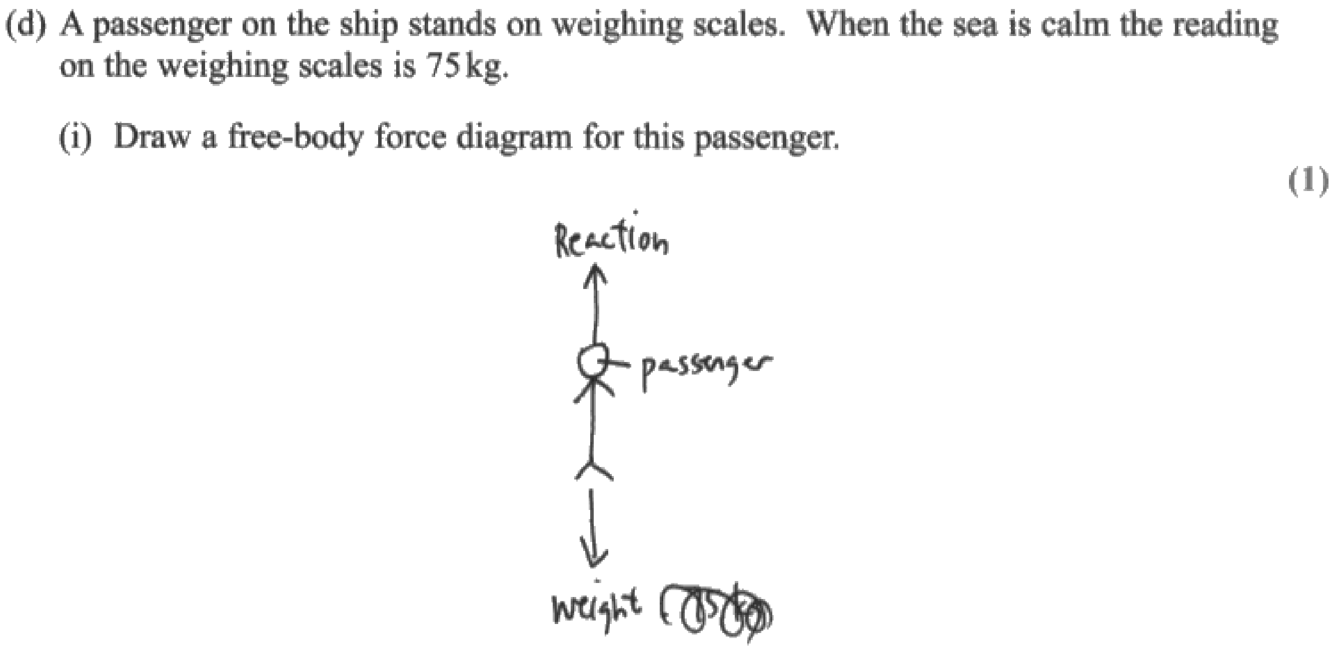
ResultsPlus
Examiner Comments

Although this student does not understand the complex situation, they do realise that they are required to find a force and that the question has given them a mass and an acceleration so they can use *F* = *ma*. This scores the 1st mark.

Question 18 (d) (i) - (ii)

(i) The standard of the free body diagrams was disappointing, especially since this should have been mastered in Unit 1. Ideally we would like to see two arrows of roughly equal length, drawn with a ruler, with a dot in the middle to represent the passenger. A free hand drawing is acceptable provided the arrows are vertical, more or less straight and the same length. Although there are a number of acceptable alternatives for the labels on the arrows, ‘upthrust’ for the upward arrow is incorrect. Upthrust is a technical term in physics and is the upward force on an object immersed in a fluid.

(ii) Whilst it is encouraging that most students made an attempt at this, the physics proved beyond the majority. It is a tricky situation to analyse but it was hoped that since the earlier parts of the question had focused students on simple harmonic motion and a free-body force diagram for the passenger, they would put these together and so make at least some progress. There were a few responses that made it clear that either the reading on the weighing scales is the normal reaction force of the scales on the passenger, for the 1st mark, or that since the motion is s.h.m. there must be a resultant force that must change direction as the passenger goes through the equilibrium position, for the 2nd mark. There were very few who could correctly put these ideas together to score the 3rd mark. Errors of physics were many and varied, including those who thought that the mass of the passenger would change and an incorrect analogy with what happens in a lift. The question is directing students to discuss forces and therefore a response solely in terms of acceleration cannot score.



(d) A passenger on the ship stands on weighing scales. When the sea is calm the reading on the weighing scales is 75 kg.

(i) Draw a free-body force diagram for this passenger.

(1)

*(ii) On a rough sea the ship oscillates vertically with a large amplitude.

Explain why the reading on the weighing scales will vary.

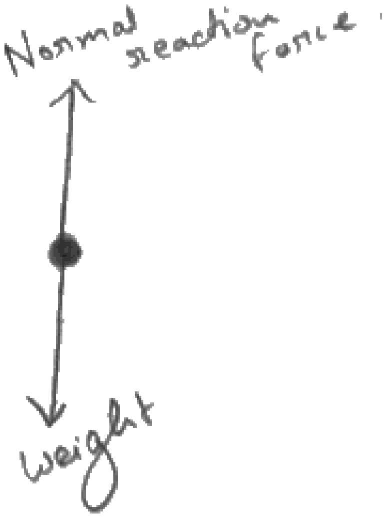
(3)

When the ship oscillations, it means there are accelerations, which means there must be a resultant force upwards or downward, since there ~~only~~ are only two forces acting on the passenger, and the weight does not change, the reaction force must be changing. And since a weighing scales measures the reaction force, the reading on the scale will vary.

ResultsPlus
Examiner Comments

(i) The labels on this diagram are correct but it is not a free-body diagram. The two force arrows should be continuous. The weight force is acting in mid air, and the reaction force seems to be on the passenger's head. Scores 0.

(ii) This is a good attempt, correctly identifying that there is a resultant force that will change direction and that the weighing scales measure the reaction force. It scores the 1st & 2nd marks.

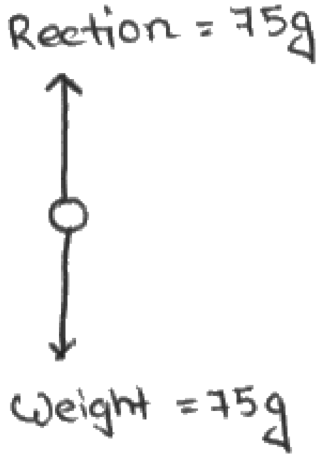


As the ship oscillates vertically, the acceleration of the passenger changes. Hence the ~~force of the passenger also changes according to F=ma. As the~~ normal reaction force on the passenger also changes. Weighing scales ~~a~~ measure the reaction force. Hence the reading changes.

ResultsPlus
Examiner Comments

(i) Two equal length straight arrows, correctly labelled but not quite vertical. This is good enough for the mark.

(ii) Scores the 1st mark for identifying that the weighing scales measure the reaction force.



- Amplitude is directly proportional to acceleration of person according to $a = -\omega^2 x$, so acceleration of ship increases as amplitude increases.
- Acceleration $\propto \frac{1}{\text{mass}}$, so mass of person decreases and reading on weighing scales decreases.

ResultsPlus
Examiner Comments

(i) A nice free-body diagram. It was not necessary to add the value of the forces to score the mark.

(ii) This is an example of one of the many incorrect approaches to the question. This student seems to have misunderstood the equation for simple harmonic motion, confusing displacement with amplitude, and thinks that the mass of the passenger decreases with increasing amplitude. No credit is given.

Paper Summary

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

- Ensure you have a thorough knowledge of the physics for this unit
- Read the question carefully and answer what is asked
- For descriptive questions, take note of the marks available and include that number of different physics points
- Learn definitions of physics terms used in this unit
- Show all your workings in calculations.

Grade Boundaries

Grade boundaries for this, and all other papers, can be found on the website on this link:

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