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Examiners' Report
June 2012

GCE Physics 6PH05 01

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Introduction

This paper gave candidates 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 11, 12(b), 13(b), 18(a), and 19(c)(iv) tended to be clustered at the lower end of the scale.

In general, calculation and 'show that' questions gave candidates an opportunity to demonstrate their problem solving skills to good effect. Some very good responses were seen for such questions, although question 19(c)(iv) exposed the inability of many candidates to apply open ended problem solving skills and to manipulate algebraic expressions correctly.

Occasionally in calculation questions the final mark was lost due to an incorrect or missing unit, as in question 13(a)(ii) where a number of candidates used °K instead of K. Unfamiliarity with the unit MeV/c2 also gave problems for some candidates in answering question 19(c)(ii).

Most candidates understood the convention that in a "show that" question it is necessary to give the final answer to at least one more significant figure than the value quoted in the question.

As is often the case, candidates disadvantaged themselves by not actually answering the question, and in not expressing themselves using suitably precise language. This was particularly the case in extended answer questions such as 14(b) and 19(d), where candidates obviously had knowledge of the topic, but could not express it accurately and succinctly. Candidates could most improve by ensuring they understand all aspects in sufficient detail and always use appropriate specialist terminology when giving descriptive answers.

There is much confusion in many candidates' eyes as to the origin of molecular potential energy. In question 14(b) many candidates thought that it arises from intra-molecular bonds, whereas others thought it was gravitational in origin. Candidates were also unclear as to the differences between ideal and non-ideal gases, with many dismissing notions of an absolute zero of temperature on account of its unattainability, rather than displaying an awareness of absolute zero as a theoretical construct.

Questions requiring a discussion or a comparison to be made are common at this level. Candidates should ensure that in comparison questions they explicitly refer how a concept applies to both situations and do so with an appropriate level of detail and specialist terminology. This would have improved the marks awarded for many of the answers to question 18(a).

Scientific terminology was used imprecisely and incorrectly in a number of responses seen on this paper. The confusion between atoms, molecules, nuclei and particles was clear from the way in which these terms were often used interchangeably. At A2 level it is to be expected that, where candidates use such terms, they do so with accuracy.

Diagrams provide important means of communicating information and we should expect A2 candidates to be able to draw diagrams to achieve this, as was helpful in answering question 15(a). In question 17(b)(ii) a sketch graph was required. For a response to gain full marks a sketch should be drawn carefully enough to be physically correct showing all the important features. Such graphs must be labelled properly with all known values marked.

It is clear that some candidates do not spend enough time reading the question before they start to write their answer. In question 11 some responses seemed to be answers to a different question that had been set previously about red-shift and the expansion of the universe.

The space allowed for responses was usually sufficient. However, candidates need to remember that the space provided does not have to be filled. In some cases it seemed that there wasn't enough space on the paper to write enough. For other candidates it seemed that once the space had been filled, they felt they had completed what was required. Candidates should be encouraged to look at the number of marks available for a question, and to sculpt their answer around this.

If candidates either need more space or want to replace an answer with a different one, they should indicate clearly where that response is to be found.

The response to the multiple choice questions was generally good with 7 of the questions having 70 % or more correct answers and only 1 with less than 50% correct answers. In order of highest percentage correct they were, Q10 (94%), Q6 (79%), Q8 (76%), Q7 (76%), Q2 (72%), Q4 (71%), Q3 (70%), Q9 (61%), Q5 (59%) and Q1 (45%).

Question 1 tested knowledge of the relationship between average molecular kinetic energy and temperature and so should have been quite straightforward. It may be that candidates were thinking of molecular speeds rather than average molecular kinetic energy.

Question 11

It was rare to see a fully correct answer to this question, with a significant number of candidates ignoring the stem of the question and making references to radiation from stars/ galaxies/planets moving away from earth and erroneous references to redshift.

Most candidates displayed a general ignorance of the present state of the Universe and of its subsequent evolution from big-bang. Apart from some who referred to the cosmic microwave background, few gained the mark for stating the radiation came from the universe itself, and even fewer that the wavelength was linked to temperature or that the universe was once much hotter/cooled on expansion.

Many candidates simply repeated the stem of the question by stating that the noise coming from all directions equally, day and night suggests that the universe is expanding. A small number of candidates thought that the 'noise' in the question referred to sound.

11 In 1965, two American scientists, Penzias and Wilson, were testing a very sensitive microwave detector. They discovered that the detector was picking up microwave "noise" at a frequency of 160 GHz that appeared to come from all directions equally. Upon investigation they found that the "noise" was the same day and night, throughout the year.

Suggest how this microwave "noise" may show evidence for an expanding universe.

(3)

This 'noise' is the radiation left over from the big bang which will have started with a very high frequency ~~but~~ and short wavelength but as the universe is expanding the wavelength has been stretched to give this lower frequency microwave. This is similar to the Doppler effect.

ResultsPlus

Examiner Comments

The response makes 2 valid points, but fails to convincingly communicate the idea that the radiation comes from the Universe itself.

ResultsPlus

Examiner Tip

Be specific and use technical terms wherever possible.

11 In 1965, two American scientists, Penzias and Wilson, were testing a very sensitive microwave detector. They discovered that the detector was picking up microwave "noise" at a frequency of 160 GHz that appeared to come from all directions equally. Upon investigation they found that the "noise" was the same day and night, throughout the year.

Suggest how this microwave "noise" may show evidence for an expanding universe.

(3)

The electromagnetic radiation from stars or galaxies is red shifted, to a longer wavelength of microwave, as they are all travelling away from Earth. It comes from all directions, because stars are travelling away in all directions .

ResultsPlus

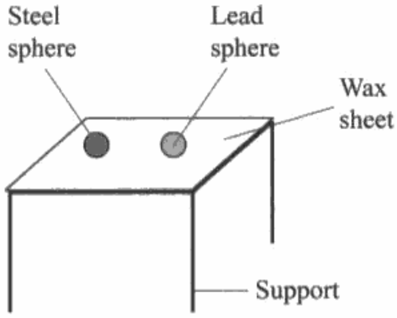
Examiner Comments

The response is typical of those from many candidates who made the assumption that the radiation comes from stars or galaxies which are moving apart.

Question 12 (a)

Most started with the correct equation, but a variety of errors occurred in the substitutions. The main errors were calculating temperature change, using the mass and/or the specific heat capacity for lead and not converting the mass to kg.

12 Two metal spheres of the same size are heated to a temperature of 100 °C in a water bath. One of the spheres is made of lead and the other of steel. The spheres are then placed onto a sheet of paraffin wax as shown. Paraffin wax melts at 55 °C.



	Mass / g	Specific heat capacity /J kg^{-1} K^{-1}
Lead sphere	50	130
Steel sphere	34	490

(a) The steel sphere melts through the wax sheet and drops to the floor. The temperature of the steel sphere when it reaches the floor is 53 °C.

Calculate the thermal energy lost by the steel sphere from the time when it was removed from the water bath.

(2)

$\Delta E = mc\Delta\theta$

$= 34 \times 490 \times (100 - 53)$

$= 783020$ J

Thermal energy lost = 783020 J

ResultsPlus
Examiner Comments

The candidate has forgotten to convert the mass of the sphere into kg.

ResultsPlus
Examiner Tip

Always check that quantities are expressed in SI units before you substitute into equations.

Question 12 (b)

Most candidates discussed the rate at which the sphere would lose energy and concluded that as the lead has a lower SHC then it would cool more rapidly, transferring energy to the surroundings more quickly, and would be below 55°C before it even got to the wax. The idea that 'the wax failed to melt completely because the time was too short' cropped up time and time again. Very few realised that a statement of thermal energy transfer to the wax was required to explain why any wax could melt. Many did not mention ideas of thermal energy transfer, resorting instead to intuitive ideas of the temperature reached by the lead sphere and its rate of cooling. Some candidates made good use of the data provided to justify answers with numerical values.

(b) The lead sphere is only able to partially melt the wax, so does not drop to the floor.

Explain this observation.

(2)

$E_L = mc\Delta\theta$

$= 50\times10^{-3} \times 130 \times (100+273-55-273)$

$= 292.5$ J

The specific heat capacity of lead is much smaller than Steel. So the thermal energy lost by lead to 55°C is smaller. then the wax sheet can not get enough energy to increase its temperature, so it can not melt, then lead sphere does not drop to the floor.

(Total for Question 12 = 4 marks)

ResultsPlus
Examiner Comments

There is an attempt to give a quantitative explanation, but there is confusion between temperature and energy required to melt the lead.

ResultsPlus
Examiner Tip

Always base your explanations of physical principles.

(b) The lead sphere is only able to partially melt the wax, so does not drop to the floor.

Explain this observation.

(2)

Specific heat capacity of lead sphere is lower.

∴ according to $E = mc\Delta t$, rate of loss of thermal energy from lead ball is less and ~~its temperature has not~~ rate at which its temperature decreases is also less so it's ~~temp.~~ temperature has not yet ~~reached~~ decreased ~~55°C~~ below 55°C.

(Total for Question 12 = 4 marks)

ResultsPlus

Examiner Comments

The candidate is considering rate of energy transfer.

(b) The lead sphere is only able to partially melt the wax, so does not drop to the floor.

Explain this observation.

(2)

The lead sphere when kept on wax sheet, heat started to transfer from sphere to wax. The lead sphere comprising less specific heat capacity comparing to ~~lea~~ steel sphere releases less energy, and thus does not drop to the floor.

(Total for Question 12 = 4 marks)

ResultsPlus

Examiner Comments

The use of English is poor, and the candidate doesn't quite say what they probably meant to say. However, there is the idea of energy transfer from the lead sphere to the wax, and insufficient energy (to melt the wax).

ResultsPlus

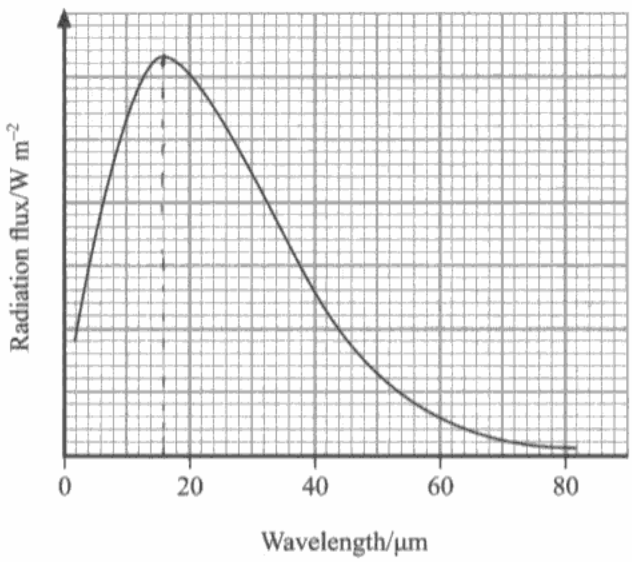
Examiner Tip

Read through your answers to ensure that what you have written makes sense.

Question 13 (a)

Candidates answered this part confidently with the majority scoring either full marks or two marks. However, not all candidates were aware that micrometres are 10^{-6} m. The majority of candidates were able to use the equation correctly. However a wide variety of units for temperature were seen including Js^{-1} and °K. The occasional candidate misinterpreted λ_{max} in Wien's Law as the highest wavelength that the graph line reached i.e. 82 μm. This was sometimes despite obtaining the correct answer in (a)(i).

13 The radiation emitted from an asteroid is monitored and the following spectrum obtained.



(a) (i) State the wavelength at which the peak radiation flux from the asteroid occurs. **(1)**

Wavelength of peak radiation flux = 16 μm = 1.6×10^{-5} m

(ii) Use the data to estimate the temperature of the asteroid. **(2)**

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

$1.6 \times 10^{-5}\ T = 2.898 \times 10^{-3}$

$T = 181.121$

Temperature of asteroid = 180° K

ResultsPlus
Examiner Comments

The unit is incorrect.

ResultsPlus
Examiner Tip

Always check units for quantities that you calculate. Know the standard SI units for all commonly met quantities.

Question 13 (b)

Many candidates had little idea and made random guesses, whilst very many thought the mass of the asteroid would be required. Of those who put mass of the Sun as one answer, a significant number were able to score both marks, but it was comparatively rare to see the gravitational constant, G, on its own. Gravitational field/force instead of was often seen instead of gravitational constant.

(b) The asteroid is in a circular orbit, of known radius, about the Sun. The average speed of the asteroid cannot be determined directly.

State the two extra data values that you would need in order to calculate the orbital period of the asteroid.

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

(2)

1 The mass of the Sun

2 The Universal Gravitational Constant

ResultsPlus
Examiner Comments

The candidate has identified the correct responses by referring to an equation from gravitational theory.

ResultsPlus
Examiner Tip

Try to relate questions to relevant theory - in this way you will be able to avoid guessing answers randomly.

Question 13 (c)

Very many correct answers were seen, although unit errors were common, with many candidates giving their answer in N, Nkg, or Nm^{-1}. The radius, r, in $F = GM/r^2$ was often not squared.

(c) This asteroid is about 1.5×10^{11} m from the planet Jupiter.

Calculate the magnitude of the gravitational field strength of Jupiter at this distance.

mass of Jupiter = 1.9×10^{27} kg

(2)

$G \frac{M}{r^2} = F$

$F = 6.67 \times 10^{-11} \left(\frac{1.9 \times 10^{27}}{1.5 \times 10^{11}} \right)$

$F = 8.45 \times 10^{5}$ N

Gravitational field strength of Jupiter = 8.45×10^{5} N

ResultsPlus
Examiner Comments

The candidate has used F instead of g, so they have erroneously quoted the units as N in their final answer.

Although they have indicated that r should be squared, the candidate has not squared r in their calculation.

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Examiner Tip

Always use standard symbols in equations.

Check that you have carried out all of the numerical processes that the equation demands.

Question 14 (a)

Most candidates succeeded in reaching the correct answer. Only a handful did the process in reverse to calculate the pressure. As well as the most common error of forgetting to add 273 to T, a surprising number of candidates added values other than 273 in carrying out the conversion. The numbers 173, 271, 293 all appeared more than once, and a few candidates subtracted T from 273.

In the specification, pV = NkT is given in the section on gases. Many textbooks use PV=nRT, and whilst this is perfectly appropriate, R will not be provided in the list of data in the examination paper.

14 A magazine article states that an inflated balloon contains about two hundred billion trillion (2×10^{23}) air molecules.

(a) Taking the balloon to be a sphere of volume 8.2×10^{-3} m^3 in a room at a temperature of 22 °C, show that this figure for the number of molecules is correct.

pressure of air in balloon = 1.1×10^5 Pa

(2)

$PV = NRT$

$(1.1 \times 10^5)(8.2 \times 10^{-3}) = N(1.5 \times 10^{-23})(22 + 273)$

$N = 2.038 \times 10^{23}$

$\approx 2 \times 10^{23}$ as required.

ResultsPlus

Examiner Comments

The candidate has used pV=NRT, which is an incorrect equation. If pV=nRT had been used, with a correct value for R, the candidate could have worked out the amount of gas present and then used the Avogadro constant to find N.

ResultsPlus

Examiner Tip

Use the standard equations given in the specification and listed on the formula sheet at the end of the exam paper.

Question 14 (b)

It is clear that some teachers are not putting across the idea of internal energy in the way that this question expected. To gain full marks students needed to understand something of ideal gases. Although most students were able to state that internal energy is made up of kinetic and potential energies they often forgot to mention particles or molecules. Surprisingly, when answers referred to potential energy it was often gravitational potential energy that was specified! Many candidates struggled to explain adequately why the statement was correct or incorrect, the main downfall being candidates' inability to string together a coherent argument using relevant physics. This was despite evidence indicating that they often appeared to know the relevant physics. Comments were usually too general, like 'heat makes the molecules move faster', or 'if temperature decreases then the energy decreases'. Many candidates only used the terminology "low enough" when referring to the temperature (rather than "absolute zero" or "0 K" as was expected). Some candidates got distracted by the experimental limitations of reaching absolute zero (missing the point that it was a theoretical consideration) reasoning that the statement could never be true as absolute zero was impossible.

*(b) The article also states that the internal energy of the air in the balloon could become zero if the temperature of the gas became low enough.

Explain what is meant by the internal energy of the air and discuss whether the statement is correct.

(4)

Internal energy is the sum of potential energy and kinetic energy. The air molecules are supposed to be Ideal gases. Ideal gas molecules ~~have no~~ are assumed to have no forces exert on each other except in collisions. At low temperature, there are few or even no collisions. There is no potential energy. Kinetic energy can be zero at low enough temperature. The statement is correct.

ResultsPlus

Examiner Comments

The answer makes a number of half correct statements. There is insufficient detail supplied for any marks to be awarded.

ResultsPlus

Examiner Tip

Use technical language carefully in answering questions such as this.

*(b) The article also states that the internal energy of the air in the balloon could become zero if the temperature of the gas became low enough.

Explain what is meant by the internal energy of the air and discuss whether the statement is correct.

(4)

Internal energy is the sum of potential energy of molecules and kinetic energy of molecules.

If the air ~~molecules~~ is ideal gas then ① Molecules will not exert force on each other except during collision so there will be no potential energy so only K.E. So when temperature become low enough then K.E of molecules will become zero so internal energy will become zero at this absolute zero temperature because only K.E is the internal energy.

(Total for Question 14 = 6 marks)

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Examiner Comments

The response gains most of the marks, but there is no clear link made between the average kinetic energy of the molecules and the temperature of the gas.

Question 15 (a)

Most candidates seemed very familiar with the method and were able to score full marks, mostly from their diagram. However, although they had learned the diagrams and words, it was clear that they were very unsure of what was really being measured by astronomers in practice. Some brought astrologers into their descriptions, and (appropriately for celestial measurements) for some, star angels were the main measurement to be made. Not all candidates were aware of the role of the fixed background of stars, and some diagrams were so poorly drawn and lacking in annotation that marks could not be awarded.

15 (a) Astronomers determine the distance to a nearby star using trigonometric parallax.

Describe the measurements that must be taken to determine this distance.

You may use a diagram to aid your description.

(2)

~~One nearby~~ The nearby same star can be pointed from in both January and June. When the astronomer point the star on January, they draw ~~create~~ a visual ~~line~~ line from earth and again when they point the same star on June again they draw a line. Two line intersect and the ~~ag~~ angle is ~~meacured~~ measured. By using ~~trigonometry~~ trigonometry the distance can be determine.

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Examiner Comments

This is an example of a response that would have scored more marks by including a diagram.

ResultsPlus
Examiner Tip

A well drawn, correctly labelled/annotated diagram can often score full marks in a question.

Question 15 (b)

Whereas most candidates recognised that there was an increase in wavelength, a few only talked about the wavelength moving to the red end of spectrum (which doesn't necessarily mean that the wavelength has increased). Disappointingly, there were still some candidates describing redshift as a change in wavelength, or frequency, rather than specifying an increase or decrease. A number of students failed to mention that the wavelength increase was caused by the apparent movement of source and observer. Where all 4 marking points were given, the QWC was excellent and easy to follow.

*(b) Radiation received at the Earth from a distant galaxy is redshifted. The distance to the galaxy can be determined from this redshift.

State what is meant by redshift, and explain how it allows the distance to the galaxy to be determined.

(4)

Due to the expansion of the universe, distant galaxies are moving away from us. Hence, radiation received at Earth are observed to have longer wavelengths than it should be due to the Doppler effect. using $z = \frac{\Delta f}{f} = \frac{v}{c}$, we can determine the speed the galaxy is moving away from us, v by using the red shift. Then, $v = Hd$ can be used to determine the distance to the galaxy.

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Examiner Comments

This is an example of a succinct, well thought out response that scores full marks without undue use of space.

ResultsPlus

Examiner Tip

Plan your answer to a question like this before you start to write. Planning your response will help you to write your answer out logically and with a minimum of repetition.

Question 16 (a) (i)

The majority of candidates scored well on this question. The most common error was to label red giants or giants as super giants. Other mistakes included using a different word from 'sequence' and giving the wrong colour for 'white' dwarfs.

(i) Identify the three main regions of the H-R diagram.

(3)

Region A = Red giant.

Region B = Normal Sequence.

Region C = White dwarfs.

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Examiner Comments

The band of stable hydrogen burning stars is called the main sequence.

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Examiner Tip

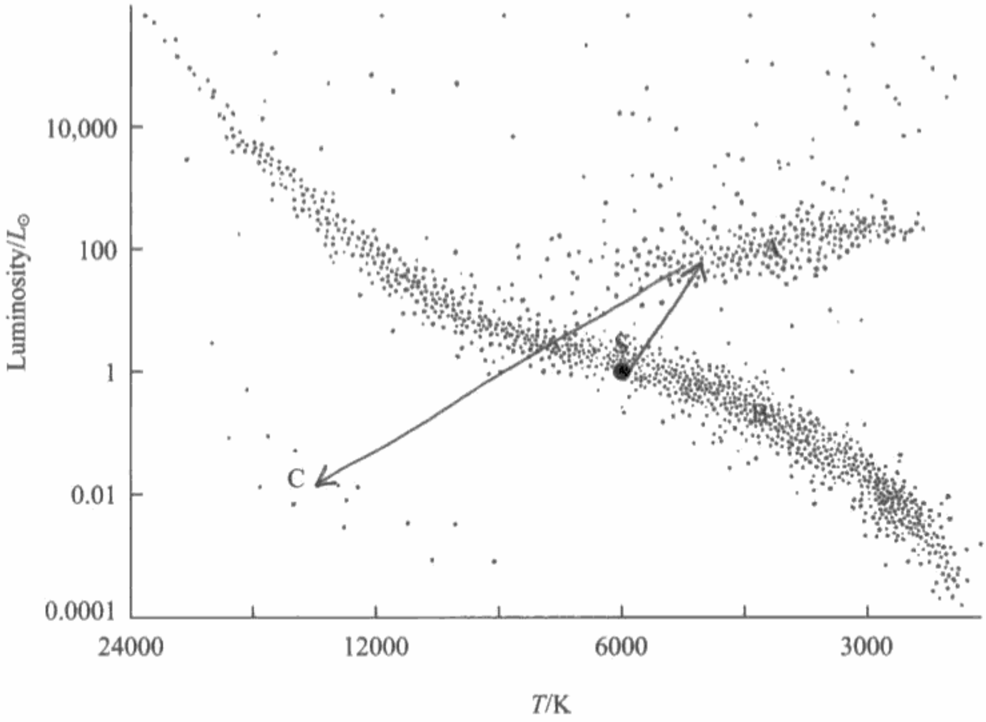
Know and use technical words correctly.

Question 16 (a) (ii)

The evolutionary path of the Sun took a variety of forms, some of which did not start at the Sun on the diagram. A good number of candidates clearly had not met stellar evolution explicitly on a Hertzsprung-Russell diagram, or couldn't relate their general understanding of stellar evolution to this diagram. A common response was for candidates to draw a straight line from S to A and also a straight line from A to C, so only scoring 1 mark. Perhaps a lot of candidates think that a 'line' must be straight. It is clear that many candidates did not have knowledge or insight into the evolution of a star. The route from a red giant star to a white dwarf involves an initial increase in surface temperature followed by a decrease in luminosity and temperature, and so the evolutionary path on the HR-diagram is clearly not a straight line from A to C.

Responses similar to the one shown here were seen quite frequently.

16 (a) The position of our Sun, S is shown on the Hertzsprung-Russell (H-R) diagram below.



(i) Identify the three main regions of the H-R diagram.

(3)

Region A = Red giants

Region B = Main sequence stars

Region C = White dwarfs

(ii) Add lines to the diagram to show the evolutionary path of our Sun from the time when it comes to the end of its hydrogen-burning phase.

(2)

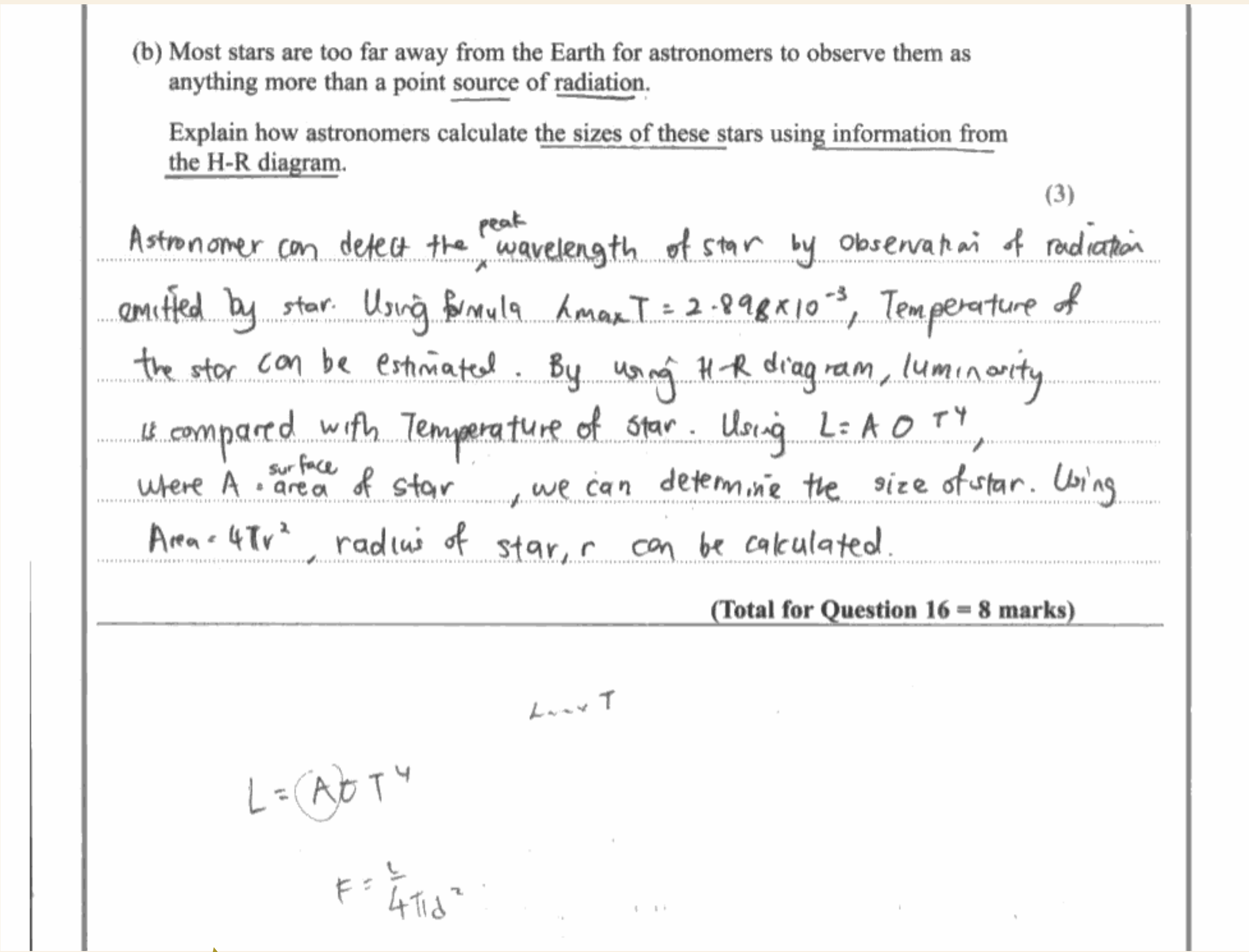
ResultsPlus

Examiner Comments

The "evolutionary path" as specified in the question implies more than an identification of the areas where the Sun is located in its life cycle. These areas are already sketched in the diagram provided in the question. The "evolutionary path" indicates a more detailed route to be followed, giving some idea of how temperature and luminosity change.

Question 16 (b)

The first 2 marking points for T and L were achieved by the majority of candidates. A few who lost out on the third mark was because they did not write down the equation for Stefan-Boltzmann law, or they did not make it explicit that they were going to use the equation to calculate the area or the radius. A surprising number referred to $F = L/4\pi d^2$, assuming that distance to star was required. Some candidates thought that size of star meant distance to star, whereas others gave a discussion of what is meant by a red giant and a white dwarf.



(b) Most stars are too far away from the Earth for astronomers to observe them as anything more than a point source of radiation.

Explain how astronomers calculate the sizes of these stars using information from the H-R diagram.

(3)

Astronomer can detect the peak wavelength of star by observation of radiation emitted by star. Using formula $\lambda_{max}T = 2.898 \times 10^{-3}$, Temperature of the star can be estimated. By using H-R diagram, luminosity is compared with Temperature of star. Using $L = A\sigma T^4$, where A = surface area of star, we can determine the size of star. Using Area = $4\pi r^2$, radius of star, r can be calculated.

(Total for Question 16 = 8 marks)

$L \propto T$

$L = A\sigma T^4$

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

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Examiner Comments

The order of information provided in the response is a little odd, but all the essential detail is included. A is identified in the Stefan-Boltzmann equation as the surface area of the star.

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Examiner Tip

Always remember to define the meanings of symbols that you use in an answer.

Question 17 (a) (i)

This was correctly answered by more than 90% of candidates. The popular incorrect response was "simple harmonic motion".

Question 17 (a) (ii)

This was done very well by the majority of students. However, some candidates referred to the driving /forcing frequency as the driving force so lost out on the first marking point. Others made no reference to the driving/forcing frequency but instead talked about the vibrations or oscillations matching the natural frequency, so also lost out on this mark. Some candidates were clearly quoting a definition they had memorised, because as soon as they tried to explain it they often went wrong.

17 The photograph shows a nodding tiger toy. The tiger is placed on a car's dashboard and its head nods up and down as the car is driven along a rough road surface.

It is noticed that at a particular speed the tiger's head vibrates with maximum amplitude.

(a) (i) What is the name of this phenomenon?

(1)

Resonance.

(ii) Describe the conditions necessary for this phenomenon to occur.

(2)

The speed of the car should be the ~~same~~ similar to the speed of oscillation of the tiger head

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Examiner Comments

The candidate doesn't refer to frequency at all.

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Examiner Tip

Learn the conditions for effects such as s.h.m., resonance etc.

17 The photograph shows a nodding tiger toy. The tiger is placed on a car's dashboard and its head nods up and down as the car is driven along a rough road surface.

It is noticed that at a particular speed the tiger's head vibrates with maximum amplitude.

(a) (i) What is the name of this phenomenon?

(1)

Resonance

(ii) Describe the conditions necessary for this phenomenon to occur.

(2)

Resonance occurs when the system is driven at it's natural frequency which causes a large increase in amplitude of the vibrations.

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Examiner Comments

The candidate goes further than just identifying the conditions for resonance, but still scores full marks.

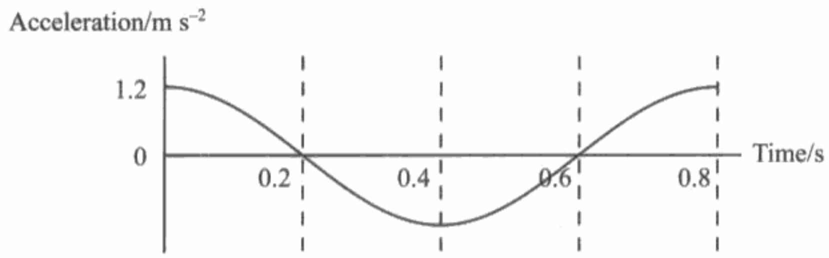
Question 17 (b)

Many correct calculations were seen. Incorrect T values and the failure to square the ω term were the main sources of incorrect answers. Some candidates include a cosωt term which also led to mistakes in some cases.

Most candidates drew the correct shape and phase of the displacement-time graph but omitted to show any amplitude or time marks on their axes.

(b) (i) The graph shows the variation of acceleration with time for the tiger's head. Using values from the graph calculate the amplitude of oscillation of the tiger's head.

(3)



$A_{max} = \omega \times A$

$T = 0.8$ seconds.

$\omega = \frac{2\pi}{0.8} = 5/2\,\pi$

$a_{max} = \omega \cdot A$

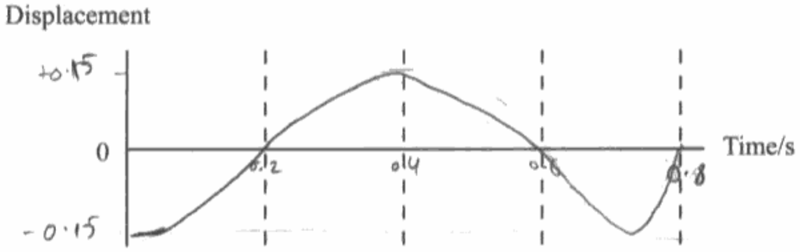
$1.2 = 5/2\,\pi \cdot A$

$A = 1.2 / (5/2\,\pi)$

Amplitude of oscillation = 0.15 m

(ii) Sketch a graph of the head's displacement against time over the same time interval on the axes below.

(2)



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Examiner Comments

In b(i) the equation for acceleration is incorrectly written down, and so the candidate only scores 1 mark for use of the formula to calculate w.

In b(ii) numerical values corresponding to those in (i) have been added to each axis. However, the graph shape is wrong between 0.6 s and 0.8 s.

ResultsPlus

Examiner Tip

Take care when sketching graphs - all essential features must be correct, and numerical values (where known) should be included on the axes.

Question 18 (a)

The main problem was that candidates were assuming the text in their answers and not giving a clear comparison between the popcorn and radioactive decay each time. The analogy was well understood but not always well expressed so that it was not clear which aspect of radioactivity was being compared to the popcorn. Some candidates seem to think that because there is something called a ‘decay constant’, this means that the rate of decay is constant; many candidates were confusing the terms ‘spontaneous’ and ‘random’. Some thought that the radioactive atoms will never all decay.

18 In a demonstration to her class, a teacher pours popcorn kernels onto a hot surface and waits for them to pop. The kernels pop one by one. There is a large rate of popping at first and this rate decreases as time goes on. However, the order in which the kernels pop cannot be predicted.

*(a) How realistic is this demonstration as an analogy to radioactive decay? Consider aspects of the demonstration that are similar to radioactive decay and aspects that are different.

(4)

in radioactive decay the decay is random and occurs with out a Stimulie, but with popcorn a certain temperature must be reached befor the popcorn kernels can pop. but the order in which the kernels pop cannot be predicted much like in radioactive decay. any part and any amount can decay. also there must be enough popcorn so it can be modlled Statisically similar to radioactive

ResultsPlus

Examiner Comments

The candidate fills the space available whilst only managing to cover two of the marking points.

18 In a demonstration to her class, a teacher pours popcorn kernels onto a hot surface and waits for them to pop. The kernels pop one by one. There is a large rate of popping at first and this rate decreases as time goes on. However, the order in which the kernels pop cannot be predicted.

*(a) How realistic is this demonstration as an analogy to radioactive decay? Consider aspects of the demonstration that are similar to radioactive decay and aspects that are different.

(4)

Similarities:

In radioactive decay, which unstable nucleus will decay cannot be predicted and ~~in this~~ here the order in which the kernels pop cannot be predicted.

The rate of decay depends on the number of undecayed nuclei remaining and here also there is a large rate of popping at first and this rate decreases with time. The exact number of kernels that will pop in a given time cannot be stated which is also true for radioactive decay. The fraction of the total no. of popcorns that will pop within a time can be stated.

Differences: The fall in rate of popping of popcorn may not be exponential.

The temperature and contact with surface affects the popping but radioactivity is not affected by temperature.

It can be acceptable if the rate of fall is exponential

ResultsPlus
Examiner Comments

The candidate has ordered their response into two sections - similarities and differences - which is a good start. However, they start off by identifying the randomness of the decay and then, having discussed the way in which decay rate decreases with time, they return to a discussion based on the randomness of the process.

ResultsPlus
Examiner Tip

Make sure that you include reference to both aspects of the analogy (popcorn and radioactive nuclei) when you refer to similarities and differences.

18 In a demonstration to her class, a teacher pours popcorn kernels onto a hot surface and waits for them to pop. The kernels pop one by one. There is a large rate of popping at first and this rate decreases as time goes on. However, the order in which the kernels pop cannot be predicted.

*(a) How realistic is this demonstration as an analogy to radioactive decay? Consider aspects of the demonstration that are similar to radioactive decay and aspects that are different.

(4)

This demonstration ~~is~~ is similar to the radioactive decay. It is because:

• ~~At first large of~~ Rate of decay decreases with increase of time but continues for a long time, so rate of popping of popcorn is high at first and decreases with time.

• The order of radioactive ~~dec~~ decay is also unpredictable ~~as~~ like ~~the~~ the order of kernels pops.

The aspect that is different is that, for decay to occur no hot surface is required; an unstable isotope decays on it's own to become stable.

ResultsPlus

Examiner Comments

This candidate has chosen a bulleted list, although they have not consistently referred to both aspects of the analogy. There are only 3 bullet points, which should indicate to the candidate that they can score a maximum of 3 marks.

ResultsPlus

Examiner Tip

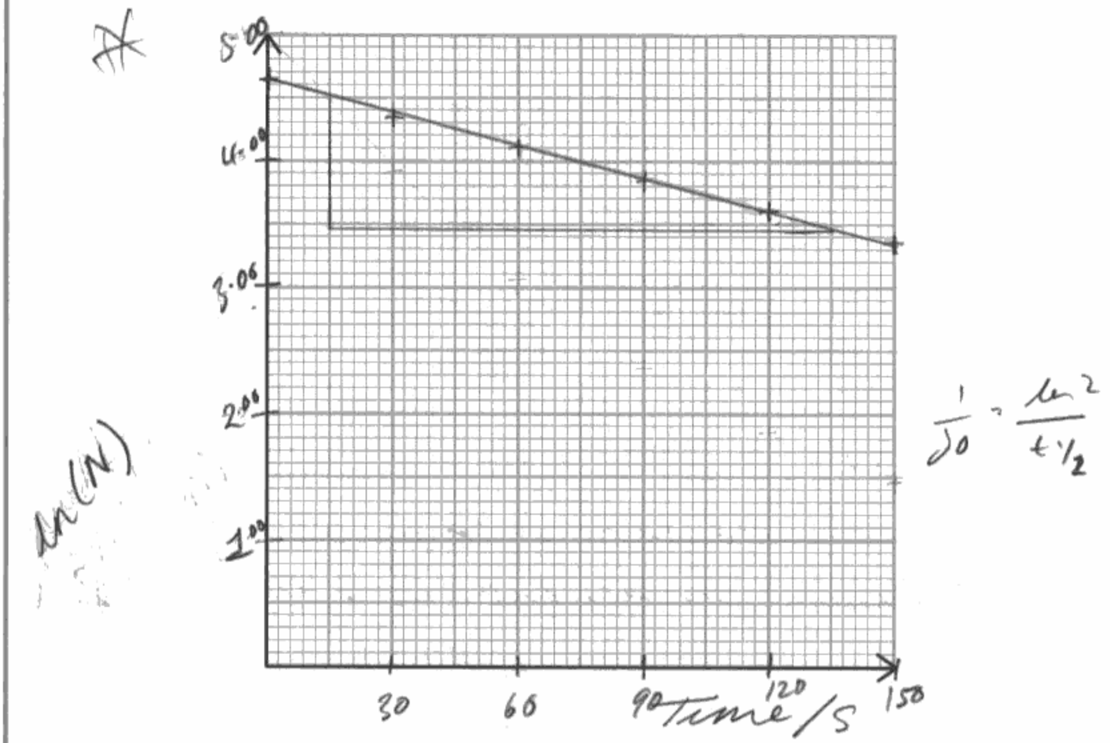
Bullet lists are often good ways of expressing key features of any effect.

Question 18 (b)

It was unfortunate that many candidates didn't realise that they should have plotted a log graph and, if they did, then that the way to get the half-life is from the gradient. Only about half of responses seen had opted for the log graph. Plotting of this graph and subsequent use of the gradient and ln2/gradient were good if seen. However, a number of candidates who drew a log-graph failed to use the gradient and a fair proportion started their 'log' axis at zero losing the appropriate scales marking point. For those who did plot a N-t graph, very few attempted to find more than one value of the half life. Use of the graph of number of kernels against time and determination of only one value of half-life perhaps indicates a lack of progression from GCSE to A2 in understanding of half-life.

A surprising number of candidates plotted using dots rather than crosses – and when a line of best fit is drawn over the top, it is very difficult to be certain where points are – candidates should expect to use an "x" for accurate plotting.

Most candidates correctly identified that 2 half lives had passed and achieved the marking point. The most common error seemed to be to half the half life rather than double it. Interestingly, many then calculated a decay constant and used this to calculate the answer to part (ii) using the decay equation, rather than the simple method of multiplying their answer to (i) by 2. Although this is perfectly valid, it is nonetheless a lot of effort for 1 mark.



$\frac{N}{N_0} = -\frac{\ln 2}{t_{1/2}} \times t$ ∴ gradient $= \frac{-\ln 2}{t_{1/2}}$

grad $= \frac{-1.05}{120} \approx \frac{7}{800}$

∴ $t_{1/2} = \frac{\ln 2 \times 800}{7} = 79.21... \approx 80\,s$

Half-life of popcorn = 80 s

(ii) A bag of popcorn is placed in the microwave oven until three quarters of the kernels have popped.

Determine the time for which the bag is in the oven.

(1)

$\frac{1}{4} = e^{-\frac{\ln 2}{80} \times t}$ $\quad -1.386 = -\frac{\ln 2}{80} \times t$

Time = 160

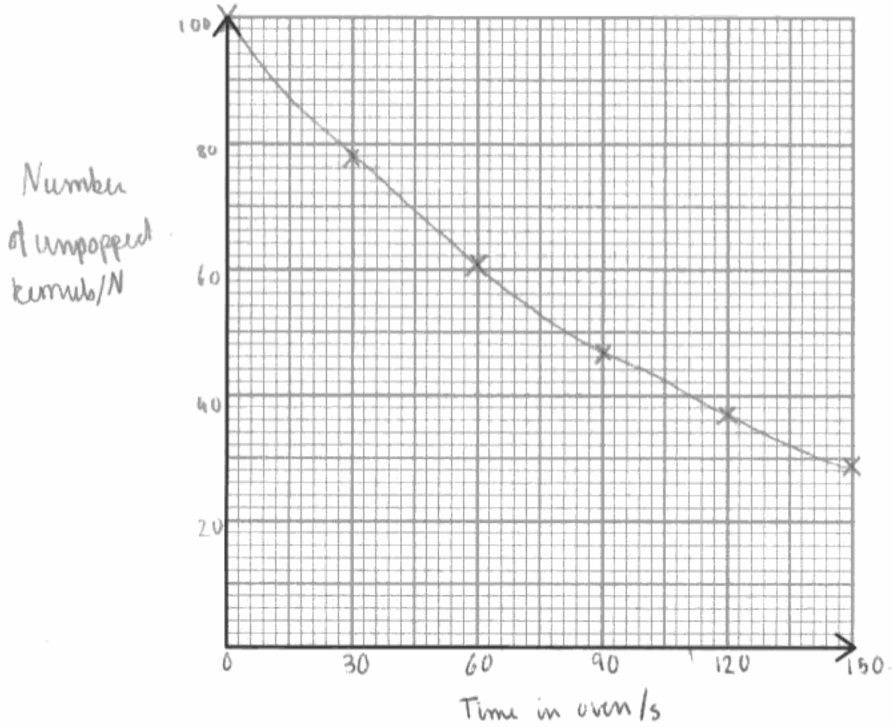
ResultsPlus
Examiner Comments

This is a good response to the question, although the vertical scale is poor.

In part (ii) the candidate chooses to carry out another calculation with the exponential equation, rather than just double their answer to part (i). Perhaps the extra effort in performing the calculation led to them omitting the units for the time, for which there is a 1 mark penalty.

ResultsPlus
Examiner Tip

Always check that you include units for quantities that you calculate.



time from 100 unpopped to 50 = 8[redacted]-0 = 8[redacted]s

time from 80 - 40 = 111-27 = 84s

time from 60 - 30 = 141 - 60 = 81s

$\frac{81+84+81}{3}$ = 82s

Half-life of popcorn = 82s

(ii) A bag of popcorn is placed in the microwave oven until three quarters of the kernels have popped.

Determine the time for which the bag is in the oven.

(1)

100 → 50 → 25 two half lifes = 82×2

= 164s

Time = 164s

ResultsPlus

Examiner Comments

Although obtaining the half life by using the exponential curve obtained from plotting N against t is not the best way to proceed, this candidate uses the curve for more than one determination of the half life and so they score 4 marks.

Question 19 (a)

Many correct answers were seen, but protons and neutrons were confused e.g. same number of neutrons, different number of protons. Also, nucleons and neutrons were confused e.g. some candidates said that tritium had 3 neutrons. A significant number thought the nuclei each contained one proton and one electron.

19 In 2010 The National Ignition Facility (NIF) in California began experiments to produce viable fusion. They used an extremely powerful laser to fuse hydrogen nuclei.

The following "recipe for a small star" was found on the NIF website:

- Take a hollow, spherical, plastic capsule about 2 mm in diameter.
- Fill it with 150 μg of a mixture of deuterium and tritium, the two heavy isotopes of hydrogen.
- Take a laser that for about 15 ns can generate 500×10^{12} W.
- Focus all this laser power onto the surface of the capsule.
- Wait at least 10 ns.

Result: one miniature star.

(a) Give one similarity and one difference between the nuclei of deuterium and tritium.

(2)

Similarity ~~proton number is same~~ Atomic number is same

Difference Mass number is different.

ResultsPlus

Examiner Comments

The two descriptions used ("atomic number" and "mass number") do not tell us what is similar/different about the nuclei. Because the atomic number is the same we can deduce that the nuclei each have the same number of protons.

ResultsPlus

Examiner Tip

Use technical language carefully.

Question 19 (b)

Most candidates scored well on this question. The 'answer' mark was sometimes lost due to giving the wrong power of ten in the answer. Some candidates did not write the final answer after they had done the multiplication and just wrote 7.5MJ.

(b) Show that the energy supplied by the laser in a time period of 15 ns is about 8 MJ.

(2)

E = Power x time

$E = 500 \times 10^{12} \times 15 \times 10^{-9}$

E = 7.5 MJ.

ResultsPlus

Examiner Comments

In this response, although we can see the substitution the calculation is not completed. We need to see the power of ten that equates to mega.

ResultsPlus

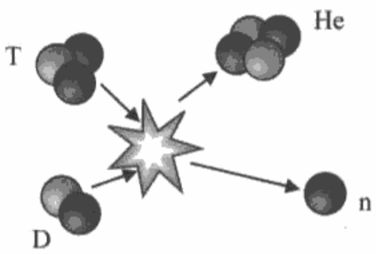
Examiner Tip

Always complete calculations fully - particularly in a "show that" question.

Question 19 (c) (i)

This was mostly correct. The most common mistakes were in the top row of values. Both rows were occasionally inverted.

(c) The diagram represents the fusion of deuterium, D, and tritium, T, to form helium, He.



(i) Complete the nuclear equation to represent the fusion of deuterium and tritium to form helium.

(2)

$$^{1}_{1}\text{D} + ^{2}_{1}\text{T} \rightarrow ^{2}_{2}\text{He} + ^{1}_{0}\text{n}$$

ResultsPlus
Examiner Comments

The top line numbers add up, but are incorrect.

Question 19 (c) (ii) - (iv)

19 (c)(ii) was a very well answered question. The vast majority of candidates understood how to perform a mass difference calculation and most did so accurately. Some candidates were unclear on how to convert the mass difference into energy – possibly not fully appreciating the benefits of using units such as MeV/c2. Some candidates made small errors on the mass difference calculation.

19 (c)(iii) was generally well answered, with many correct answers seen. Most errors were caused by a failure to convert to a consistent set of units.

19 (c)(iv) was a challenging question which many candidates struggled with. A number of prompts were given in the question but not all candidates were able to use these to frame an answer. Many candidates scored zero here, the most common approach being to throw down KE equations and plug in various numbers (including 3 x 108 ms-1 for particle speed) in the hope of getting the right answer. Some very good, concise answers were seen where the calculation was completed efficiently. Those candidates who took the hint about momentum often went on to correctly express total kinetic energy as 17.5MeV and succeeded in calculating the kinetic energy of the neutron.

(ii) Use the data in the following table to show that about 20 MeV of energy is released when this fusion reaction takes place.

	Mass / MeV/c²
Neutron	939.6
Deuterium	1875.6
Tritium	2808.9
Helium	3727.4

(2)

$\Delta m = (1875.6 + 2808.9) - (3.727,4 + 939.6)$

$= 17.5\ MeV/c^2$

$\Delta E = \Delta m c^2 \qquad \Delta E = 17.5 \times (3 \times 10^8)^2$

ResultsPlus

Examiner Comments

Although the mass difference is correctly calculated the candidate is unsure of the units [MeV/c²] and hence tries to involve c².

ResultsPlus

Examiner Tip

Learn the non-SI units used regularly in particle physics.

(iii) Estimate the number of fusions that need to take place in 15 ns if the "miniature star" is to produce the same amount of energy as the laser supplies.

(2)

$7.5 \times 10^6 = 17.5\ \text{MeV} \times \text{number}$

$7.5 \times 10^6 = 17.5 \times 10^6 \times 1.6 \times 10^{-19} \times n$

$\text{number} = 2.68 \times 10^{18}$

Number of fusions = 2.68×10^{18} //

(iv) Calculate the kinetic energy, in MeV, of the neutron released by the fusion of deuterium and tritium nuclei. Assume that the net momentum of the nuclei before fusion is zero.

(4)

net momentum after fusion is zero

$m_1 v_1 = m_2 v_2$

$3727.4(v_1) = 939.6(v_2)$ — ①

$\frac{1}{2}(3727.4)\,v_1^2 + \frac{1}{2}(939.6)\,v_2^2 = 17.5\,\text{MeV}$ — ②

~~$v_1 = \frac{4698}{18637} v_2$~~

~~$\frac{1}{2}(3727.4)\left(\frac{4698}{18637}\right)^2 v^2 + \frac{1}{2}(939.6 v_2^2) = 17.5\,\text{MeV}$~~

$v_1 = \frac{4698}{18637} v_2$ + ~~KE of neutron~~

$KE = 17.5 \times \frac{939.6}{939.6 + 236.85}$

$= 13.98\ \text{MeV}$

Neutron kinetic energy = 13.98 MeV

ResultsPlus
Examiner Comments

Full marks for both parts.

(iii) Estimate the number of fusions that need to take place in 15 ns if the "miniature star" is to produce the same amount of energy as the laser supplies.

(2)

No. of fusions = $\frac{7.5 \times 10^6}{17.5 \times 10^6 \times 1.6 \times 10^{-19}}$ = 2.68×10^{18}

Number of fusions = 2.68×10^{18}

(iv) Calculate the kinetic energy, in MeV, of the neutron released by the fusion of deuterium and tritium nuclei. Assume that the net momentum of the nuclei before fusion is zero.

(4)

K.E. = $\frac{p^2}{2m}$

for neutron : $\frac{p^2}{2u}$

for helium : $\frac{p^2}{2 \times 4u}$ = $\frac{p^2}{8u}$

17.5 MeV = $\frac{p^2}{2u} + \frac{p^2}{8u}$ = $\frac{5p^2}{8u}$

$\frac{p^2}{2u}$ = $\frac{17.5 \times 4}{5}$ = 14 MeV

∴ K.E. of neutron = 14 MeV

Neutron kinetic energy = 14 MeV

ResultsPlus
Examiner Comments

Full marks for both parts.

Question 19 (d)

This answer just required detailed recall, but a large proportion did not manage all of this. It was not uncommon for students to talk about atoms instead of nuclei. Neutrons were fired at rather than into nuclei, but not absorbed. Uranium nuclei split into lighter elements, not 2 nuclei or fragments, and neutrons released were not mentioned. Very few good 'tight' answers were seen. Whilst many students clearly had a general idea about the process of fission, many missed out key technical language. Some students went on to detail other aspects of the fission reactor, not required by this question. Some candidates need to learn the difference between fission and fusion.

(d) Nuclear power stations currently use the process of fission to release energy. Outline the process of fission.

(3)

A high energy particle is fired at ~~unstable~~ nuclei, which results in them splitting into different elements. this releases a lot of energy but also produces radioactive waste as the new nuclei are unstable.

ResultsPlus

Examiner Comments

A not atypical response with much that comes close to a correct description, but not enough to meet any of the marking points.

ResultsPlus

Examiner Tip

When outlining a process you need to be clear what is happening at each stage. A bulleted list is often helpful.

(d) Nuclear power stations currently use the process of fission to release energy. Outline the process of fission.

(3)

In fission, a slow moving neutron is collided with a large nucleus so that the nucleus absorbs the neutron becomes unstable and ~~decays int~~ splits into smaller nuclei and neutrons. The mass of the neutrons and the products is less than the sum of mass of the large nucleus and neutron. The mass deficit is converted into energy which is harnessed in the nuclear reactor. The neutrons produced are used to carry out more fusions in a controlled manner in chain reactions

(Total for Question 19 = 17 marks)

TOTAL FOR SECTION B = 70 MARKS

TOTAL FOR PAPER = 80 MARKS

ResultsPlus

Examiner Comments

There is enough here for full marks, although the organisation of the response could have been better.

ResultsPlus

Examiner Tip

Structure your answers to aid understanding. Try not to use more space than is provided - think before you begin to write.

Paper Summary

In order to improve their performance candidates should:

- Ensure they have a thorough knowledge of the physics for this unit.
- Read the question and answer what is asked.
- For descriptive questions, make a note of the marks and include that number of different physics points.
- Show all their workings in calculations.
- For descriptive questions, try to base the answer around a specific equation which is quoted.

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