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June 2013

GCE Physics 6PH05 01

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Introduction

This is the seventh time that Unit 5 of the specification has been examined. The assessment structure mirrors that of other units in the specification, consisting 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 such as electricity and waves from Unit 2.

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 15(b), 16(b), 16(d), 17(a), and 17(b)(i) 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, with solutions which were well crafted, clearly set out and accurate.

Occasionally in calculation questions the final mark was lost due to a missing unit. Most candidates understood the convention that in the "show that" question it was necessary to give the final answer to at least one more significant figure than the value quoted in the question.

There is still evidence that some candidates have problems in appreciating the magnitudes of values that they calculate, accepting their answer irrespective of whether or not it is sensible. This was particularly noticeable in 17(b)(ii) with energy per fusion, where answers many orders of magnitude larger than the correct answer were routinely accepted by candidates as being correct.

Once again, there were examples of candidates disadvantaging themselves by not actually answering the question, or by not expressing themselves using suitably precise language. This was particularly the case in extended answer questions such as 14 and 17(a), where candidates sometimes 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.

Scientific terminology was used imprecisely and incorrectly in a number of responses seen on this paper. Once again there was confusion demonstrated between atoms, molecules, nuclei and particles. 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 14. In question 13(b) a sketch graph was required. Although some candidates added guiding points to help them draw the curve, this was not always the case. Inaccurate sketching of the (-) cosine curve led to marks not being awarded.

It is clear that some candidates do not spend enough time reading the question before they start to write their answer. In question 16(b) some responses focused on experimental detail rather than interpretation of data.

The space allowed for responses was usually sufficient. However, candidates need to remember that the space provided does not have to be filled. Candidates should be encouraged to consider the number of marks available for a question, and to use this to inform their response.

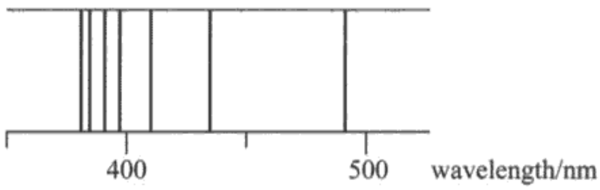
The response to the multiple choice questions was generally good with 8 of the questions having 70 % or more correct answers and none with less than 50% correct answers.

In order of highest percentage correct they were: Q10 (95%), Q6 (89%), Q9 (81%), Q3 (80%), Q5 (76%), Q1 (73%), Q4 & Q7 (72%), Q8 (68%) and Q2 (64%).

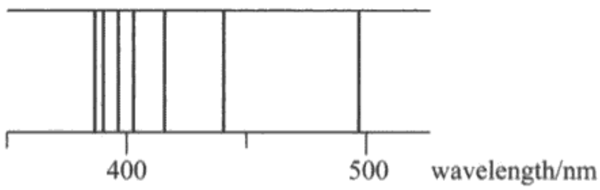
Question 11

Many candidates knew that the wavelength shift was a red (or Doppler) shift due to the galaxy receding from Earth. However, some candidates simply referred to a ‘shift towards the red end’ without stating red shift so lost out on mp1. Responses indicating that the ‘universe is expanding’ and even ‘galaxy expanding’ and occasionally ‘blue shift so galaxy coming towards Earth’ were seen. However, marking point (mp) 2 was typically lost because students failed to note the relative motion between source and observer, i.e. they simply said ‘moving away’, which left open the question of what is moving away from what.

11 The diagram shows part of the hydrogen line spectra obtained for radiation emitted from hydrogen in the laboratory and received from hydrogen in a distant galaxy.



Laboratory Spectrum



Distant Galaxy Spectrum

The lines in the distant galaxy spectrum are all shifted in wavelength compared to the lines in the laboratory spectrum.

State why the lines are shifted and what we can conclude about this distant galaxy.

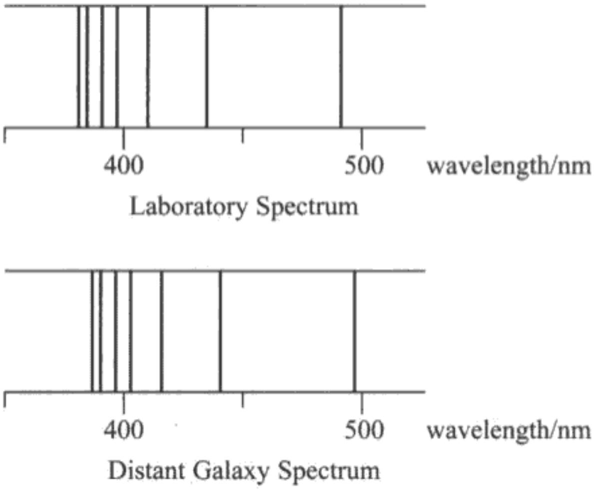
(2)

The lines are shifted due to the doppler effect. The actual wavelength is ~~less than~~ ~~greater~~ less than the observed wavelength. It's called a red shift. The galaxy is moving away from the Earth.

ResultsPlus
Examiner Comments

This response scores both marks, as there is a reference to the Doppler effect and it is clearly stated that the galaxy is moving away from the Earth.

11 The diagram shows part of the hydrogen line spectra obtained for radiation emitted from hydrogen in the laboratory and received from hydrogen in a distant galaxy.



The lines in the distant galaxy spectrum are all shifted in wavelength compared to the lines in the laboratory spectrum.

State why the lines are shifted and what we can conclude about this distant galaxy.

(2)

Apparent wavelength is greater than the actual wavelength.
So the ~~star~~ galaxy is moving away (red-shift).

ResultsPlus
Examiner Comments

This response gains the marks for a reference to red shift, but has not stated what the galaxy is moving away from and so the second mark is not awarded.

Question 12 (a)

Candidates answered this question very well, with nearly all scoring full marks. A very small proportion lost the second mark mainly due to a power error. Use of I = P/V and R = V/I and the mark scheme method were equally popular ways of obtaining the correct answer with units. There were very few algebraic errors and kW was usually converted into W correctly.

12 The heating element of an electric shower has a power of 6.0 kW.

(a) The shower is operated from a 230 V mains supply.

Calculate the resistance of the heating element.

(2)

$P = \frac{V^2}{R} = \frac{(230)^2}{R} = 6\text{kW}$

power = 6kW

voltage = 230V

6×10^{-3}

Resistance = $8.8 \times 10^{6}\ \Omega$

ResultsPlus
Examiner Comments

The "use of equation" mark is awarded, but the final answer has the wrong power of 10. The candidate has converted kW into W incorrectly.

ResultsPlus
Examiner Tip

Learn the power of 10 conversions for the standard SI prefixes.

12 The heating element of an electric shower has a power of 6.0 kW.

(a) The shower is operated from a 230 V mains supply.

Calculate the resistance of the heating element.

(2)

P = 6000

V = 230

R = ?

$P = \frac{V^2}{R}$ $R = \frac{V^2}{P} = \frac{230^2}{6000}$

Resistance = 8.82

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Examiner Comments

The final mark is not awarded, as units are omitted.

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Examiner Tip

Always check units for quantities that you calculate.

Question 12 (b)

Nearly all candidates scored the temperature mark, although sometimes candidates unnecessarily converted to kelvin before subtracting values. Occasionally, the temperature difference was wrongly converted to kelvin. Many could not link energy transferred to rate of energy transfer so were unable to calculate the water flow rate.

A common incorrect answer seen was E= 1 x 4 200 x 30 =12 600J, where mass was taken to be 1 and the energy value obtained was taken as the flow rate.

Several candidates tried to calculate v by writing mcΔT= ½mv², and responses which equated mcΔT to VIt were seen on more than one occasion.

(b) Water enters the shower at a temperature of 7.5 °C.

Calculate the water flow rate required to give an output temperature of 37.5 °C.

specific heat capacity of water = 4200 J kg⁻¹ K⁻¹

(3)

$\theta_2 - \theta_1 = 37.5 - 7.5 = 30\,k$

~~E = m c θ~~

$VIt = mc\theta$

$\frac{m}{t} = \frac{c\theta}{VI}$

$= \frac{4200 \times 30}{230 \times 26.1} = 20.98\,kg\,s^{-1}$

$21\,kg\,s^{-1}$

Flow rate = ~~20.9 kg s⁻¹~~

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Examiner Comments

The candidate has calculated a temperature difference, but re-arranged the question incorrectly before substituting values. Hence this response is awarded just 1 mark.

ResultsPlus
Examiner Tip

Substitute values before re-arranging equations, as a substitution into an incorrectly re-arranged equation will not be given the "use of equation" mark.

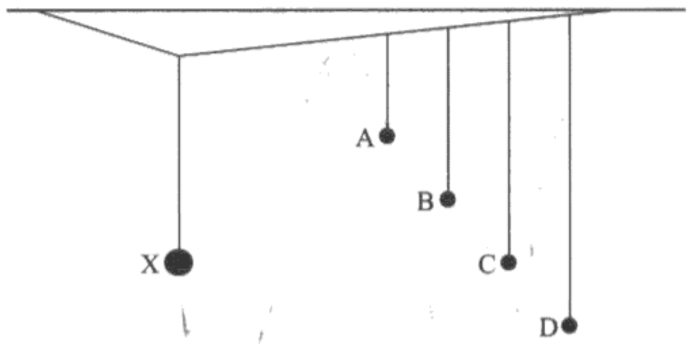
Question 13 (a)

Candidates who knew about resonance were able to give good explanations in terms of driver frequency and natural frequency. A small proportion of candidates who seemed unfamiliar with resonance invented their own explanations with very little success. The weakest responses worthy of credit usually made reference to resonance, whereas better responses included well written, detailed accounts in answer to the question.

Many candidates understood that the driven pendulum C had the same natural frequency as the driver pendulum X, but some candidates, instead of stating that C had the same length as X, said that it was at the same height.

Vague descriptions were common and it was difficult to award any mark at times as candidates were not referring clearly to X and C, nor specifying which pendulum was the driver pendulum. It was quite common for a response to explain the conditions for resonance in general terms, but fail to apply it to this case in particular. This may suggest that some candidates are learning standard answers without an understanding of how the physics relates to practical situations. A minority of candidates confused the apparatus with "Newton's Cradle" and referred to energy transfer occurring when the bobs collided.

13 The diagram shows a number of pendulums hanging from a single thread. Pendulum X has a heavy lead sphere as the bob and the others have low mass bobs. When X is set into motion energy is transferred to the others which all begin to oscillate.



After a short time C is observed to have the largest amplitude of oscillation.

(a) Explain why pendulum C has the largest amplitude of oscillation.

(3)

When pendulum X is made to ~~vib~~ oscillate, it forces A, B, C and D to oscillate. For C the natural frequency is the same as the forced frequency because both strings attaching the two pendulums X and C are of the same length. Resonance occurs and C absorbs energy and vibrates at a greater amplitude.

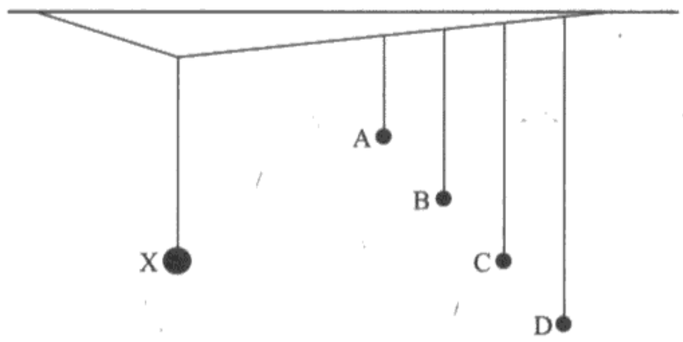
ResultsPlus
Examiner Comments

This is a concise answer which scores all 3 marks.

ResultsPlus
Examiner Tip

Structure your answers to aid understanding.

13 The diagram shows a number of pendulums hanging from a single thread. Pendulum X has a heavy lead sphere as the bob and the others have low mass bobs. When X is set into motion energy is transferred to the others which all begin to oscillate.



After a short time C is observed to have the largest amplitude of oscillation.

(a) Explain why pendulum C has the largest amplitude of oscillation.

(3)

When X is in motion the pendulum c is forced to oscillate, it absorbs energy, and the natural frequency of c has become equal to the ~~forced~~ f frequency ~~which was at~~ frequancy at which the X oscillates. ~~It is~~ which means c has obtained the max amplitude and resonating. Resonance occured.

ResultsPlus
Examiner Comments

There is probably enough understanding from this candidate for all 3 marks to be obtained. However, the wording is clumsy and the meaning is not as clear as it needs to be. A bullet list with 3 key points might have clarified what the candidate was trying to say.

ResultsPlus
Examiner Tip

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

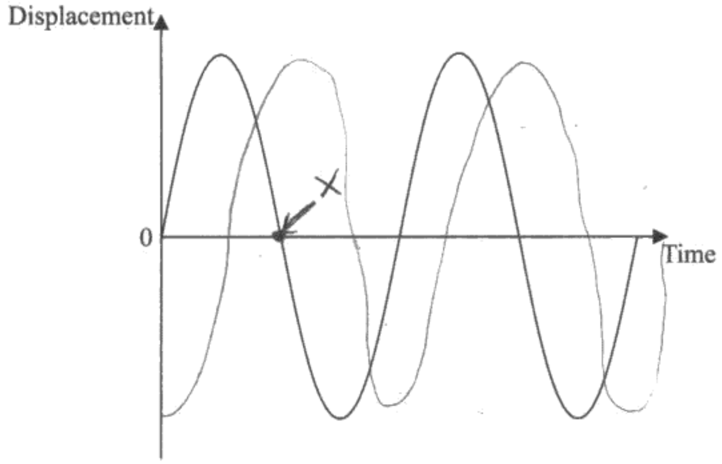
Question 13 (b)

Most candidates gained mp1 for labelling P and many sketched an appropriate curve. However, mp2 was lost for a variety of reasons: inability to express the phase relationship (given in words) to a graph, a failure to read the question carefully and sketch 2 time periods, and a lack of care in sketching.

Although many sine wave curves were drawn carefully and with attention to detail of crossing points on the x-axis, some of the curves were quite poorly drawn. A very common error was to start by drawing a cosine graph which then became a sine curve after the first zero displacement point. In such questions it is recommended that candidates add some guiding points to help them draw the curve.

The correct negative cosine curve was quite rare and the most common incorrect answer was a 'reverse sine' graph.

(b) For an efficient energy transfer pendulum C must be at rest when pendulum X has its maximum kinetic energy. The graph below shows how the displacement of pendulum X varies with time.



Mark a point P on this graph showing an instant when pendulum X has a maximum kinetic energy, and add a curve to show how the displacement of pendulum C varies over the same time interval.

(2)

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Examiner Comments

P is correctly identified, and the graph is just accurate enough to allow the second mark to be awarded.

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Examiner Tip

Take care when sketching graphs – all essential features must be correct. It may help to draw guiding points to help you draw the curve

Question 14

Although quality of written communication was assessed in this question, the use of a diagram for the parallax method helped enormously in candidates' ability to express themselves clearly. Those candidates who did not use a labelled diagram required very high level language skills to adequately make all the points necessary for a complete answer.

Parallax.

It was generally realised that observations of the nearby star were taken at six month intervals in the Earth's orbit of the Sun. Many realised that the angular position of the nearby star was measured relative to fixed or distant stars and that trigonometry was used along with the known diameter of the Earth–Sun orbit radius to calculate the distance to the star. The main reasons why candidates failed to score marks were by neglecting to state that the change in angular position of the star should be measured against fixed or distant stars (not just 'background' stars), for mp 2 and neglecting to state that the diameter/radius of the Earth's orbit must be known, or to quote/show '1AU' on their diagram for mp 3.

Standard Candle.

Many candidates stated that the luminosity of a standard candle is known (sometimes giving correct but unnecessary descriptions of how this is known). In addition, the need to measure the intensity of the standard candle was often stated. Fewer mentioned that the inverse square law was used to calculate the distance to the distant star, often preferring to give the formula instead, but not defining the quantities.

Some descriptions of how a standard candle is used to find the distance to another star/object highlighted areas of misconception that need to be addressed when teaching this topic. Surprisingly often students referred to finding a standard candle with the same flux (or luminosity) as the star of interest, and then using information about this star (and not the standard candle) to find distance. For these candidates the idea that the flux of the standard candle is measured and from a knowledge of the luminosity of the standard candle and applying the inverse square law the distance is found, and only then by assuming a physical co-location in space (i.e. the star of interest being in the same star cluster as the standard candle) can the distance be applied, seemed to be unknown.

*14 Parallax measurements are used to determine the distance to nearby stars, but this method is unsuitable for more distant objects.

Outline how parallax measurements are used to determine the distance to nearby stars and explain how the use of a standard candle enables the distance to more distant objects to be determined.

(6)

Parallax method involves standing on opposite sides of the earth and taking certain measurements from both sides and the making calculations to work out the distance.

Standard candle takes into account the radiation energy emitted by the star and the Lumonisity and check it against what we know then use:

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

where F is the radiation energy and L is the Luminosity of the star.
using that equation, rearrange it for d and solve wit the known values of F and L of the star.

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Examiner Comments

This response says little that is creditworthy with regard to parallax measurements, although for the standard candle method the radiation flux equation is explained. However, it is not explicitly stated that flux has to be measured from the Earth, nor is it made clear that the luminosity is known and so this response is limited to just one mark.

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Examiner Tip

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

For nearby objects parallex method is used. What happens, is that, just as we cross a tree while driving a car, ~~wee~~ we see it run in the opposite direction, we make an angle with the tree as we pass it, a sudden change in angle shows that the tree is very close to us. Similarly, ~~when earth is at~~ we take an angle from the surface of earth to the star, after a certain amount of time, the earth revolves and we ~~t~~ take the angle of the star again. By comparing angle with the time elapsed, distance to the nearby object can be determined.

when measuring distance for distant objects, candle method is used. Candle lights from distant galaxies are picked up, their wavelengths and ~~tea~~ luminosities are calculated and then compared with ~~the~~ standard candles to estimate how far the certain object/galaxy is.

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Examiner Comments

There is nothing in this response which allows any marks to be awarded.

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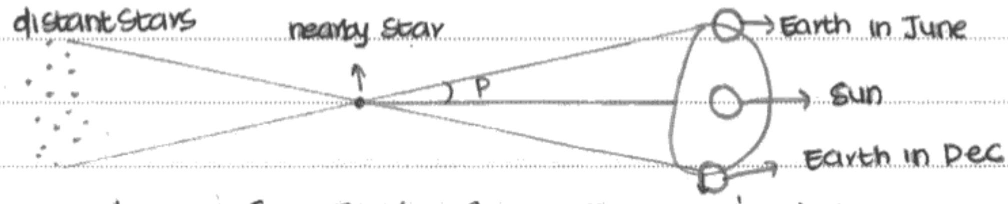
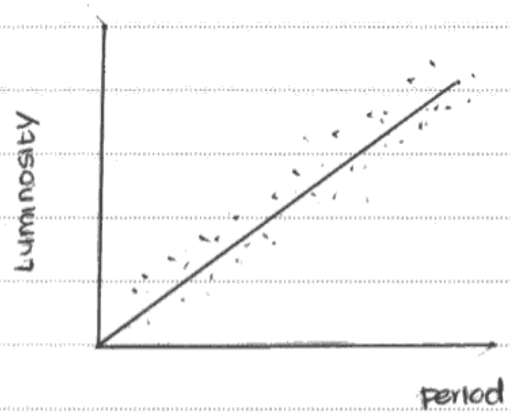
Examiner Tip

Be specific and use technical terms wherever possible.



$\tan\theta = \dfrac{\text{distance from Earth to Sun}}{\text{distance from Sun to star}}$



cepheids are standard candles that change ~~there~~ luminosity periodically. the luminosity of the cepheid can be found using H-R diagram. there is a linear relation between period and luminosity.

~~using~~ $L = \sigma T^4 A$

L :- luminosity

σ :- stefan-boltzman's constant

A :- area = $4\pi d^2$

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Examiner Comments

Through the use of the diagram the candidate has communicated enough for full marks to be awarded for the parallax part of the question. However, the reference to Cepheid variable stars and Stefan's law does little to add to our understanding of how standard candles are used to determine distances.

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Examiner Tip

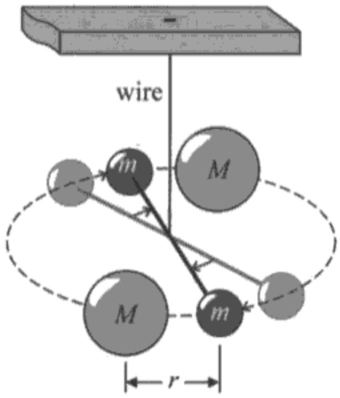
A well drawn, correctly labelled/annotated diagram can often help to score full marks in a question.

Question 15 (a)

This part was answered very confidently, with nearly all scoring full marks. Forgetting to square r was an occasional mistake that resulted in marks not being awarded.

15 In the 18th century Henry Cavendish devised an experiment to determine the average density of the Earth. This involved the first laboratory determination of the universal gravitational constant G.

A light horizontal rod with a small metal sphere at each end was hung from a fixed point by a very thin wire. Two large lead spheres were then brought close to the small spheres causing the rod to oscillate and then settle into a new position of equilibrium.



(a) In a modern version of the experiment the following data was obtained:

mass of large lead sphere $M = 160$ kg

mass of small sphere $m = 0.75$ kg

distance $r = 0.23$ m

gravitational force between adjacent large and small spheres $F = 1.5 \times 10^{-7}$ N.

Use this data to calculate a value for G.

(2)

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

$1.5 \times 10^{-7} = \frac{G \times 160 \times 0.75}{(0.23)^2}$

$1.2 \times 10^{2} G = 7.9 \times 10^{-9}$

$G = \frac{7.9 \times 10^{-9}}{1.2 \times 10^{2}}$

$G = 6.6 \times 10^{-7}$ $\mathrm{Nm^2\,kg^{-2}}$

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Examiner Comments

The "use of equation" mark is awarded, but there is a power of 10 error, so the second mark is not given.

Question 15 (b)

(b)(i)

It often proved difficult to award the first marking point as many candidates simply calculated T using single cycles rather than three cycles together. The need to measure t for a large number of cycles (and hence measure a long time) to obtain an accurate value for T was not understood by the majority of candidates. As a result the value for T was often not accurate. The single time period was often read inaccurately and in addition incorrect units were sometimes given; the units commonly appeared instead of min.

(b)(ii)

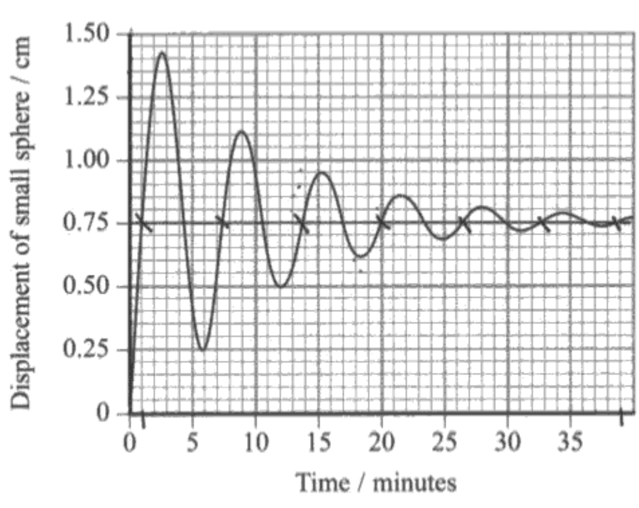
The idea that the system was damped and as a result energy was lost from it was by far the most common answer. Quite a few responses showed a lack of basic understanding of the physics, ascribing the damping to the gravitational forces applied by the large spheres. The damping mechanism was often linked to air resistance but this was not linked to the movement of the sphere. It was difficult to award mark point 1 because candidates failed to say what the resistive force was acting on. Reference to work being done was very rare.

(b)(iii)

This question was poorly answered with very few scoring full marks. Candidates did not know how to test for exponential behaviour. Many candidates were only able to score one mark either by reading the peak values correctly to score mp 1, or by using peaks of graph to sketch a curve and simply saying that it looked like an exponential curve to score mp 4.

In method 1 the peak values were often reasonably accurately measured but the amplitude was seldom calculated before ratios were calculated. Those candidates who calculated amplitude values seldom knew what to do with them to prove the relationship. However, it was encouraging to see a small number scoring full marks by successfully calculating half-life or by calculating the "decay constant". Exponential decay occurs in both Unit 4 and Unit 5, and it is to be expected that candidates should have a greater ability to transfer knowledge from the applications in these units to other situations where exponential processes take place.

(b) The graph shows how the displacement of one of the small spheres varies with time.



(i) Use the graph to determine the period of oscillation of the sphere.

(2)

6 waves → 38 minutes → 2280 s

1 wave → x

$x = \frac{2280}{6} = 380$ s

(ii) The amplitude of the oscillation decreases with each cycle.

Explain why this effect is observed.

(2)

There is a ~~dr~~ drag force (air resistance) acting on the small spheres. This causes damping and the spheres decelerate. So amplitude decreases.

(iii) It is suggested that the decrease in amplitude is exponential. Use the graph to determine if this is approximately true.

(3)

Crest 1 : Crest 2 = 0·68 : ~~1·10~~ 0·35 = 1·94
Crest 2 : Crest 3 = 0·35 : 0·2 = 1·75 } ≈ same
Crest 3 : Crest 4 = 0·2 : 0·1 = 2.

OR. Crest 1 : trough 1 = $\frac{0·68}{0·5}$ = 1·36
Crest 2 : trough 2 = $\frac{0·35}{0·25}$ = 1·40 } = constant
Crest 3 : trough 3 = $\frac{0·2}{0·15}$ = 1·33

The ratios are constant, ∴ it is exponential.

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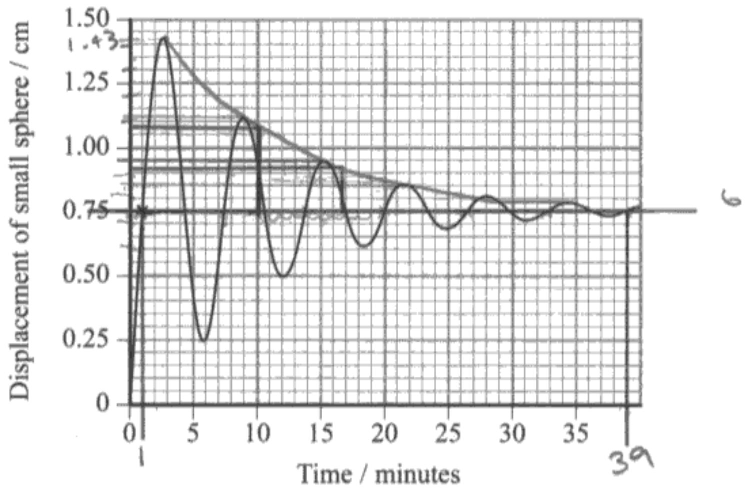
This response scores full marks in all 3 sections. Although the derivation of the amplitudes from readings on the graph in (b)(iii) is not explicit, there is enough for all 3 marks to be awarded.

(b) The graph shows how the displacement of one of the small spheres varies with time.



(i) Use the graph to determine the period of oscillation of the sphere.

(2)

no. oscillations = 6 T = 38/6

time for 6 = 39 − 1

= 38s T = 6.3

T = 6.3s

∴ Period of 1 oscillations

Period = 6.3s

(ii) The amplitude of the oscillation decreases with each cycle.

Explain why this effect is observed.

(2)

The amplitude decreases because small amounts of damping will occur naturally, caused by overcoming air resistance and friction from the string. This means that after each oscillation more and more energy is transfered to try and overcome the damping and so kinetic energy of the sphere decreases a so the amplitude does

(iii) It is suggested that the decrease in amplitude is exponential. Use the graph to determine if this is approximately true.

(3)

~~height of~~ Amplitude of first peak = 1.43 − 0.75 = 0.68

2nd = 1.12 = 0.37 ∴ log of amplitudes:

3rd = 0.95 = 0.20 0.68 = −0.167

4th = 0.85 = 0.10 0.37 = −0.432

5th = 0.~~76~~ 81 = 0.06 0.20 = −0.699

6th = 0.79 = 0.04 0.10 = −1.00

0.04 = ~~13~~ −1.398

half life = 0.68 ÷ 2 = 0.34

∴ every ~~10s~~ 9s

(Total for Question 15 = 9 marks)

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Examiner Comments

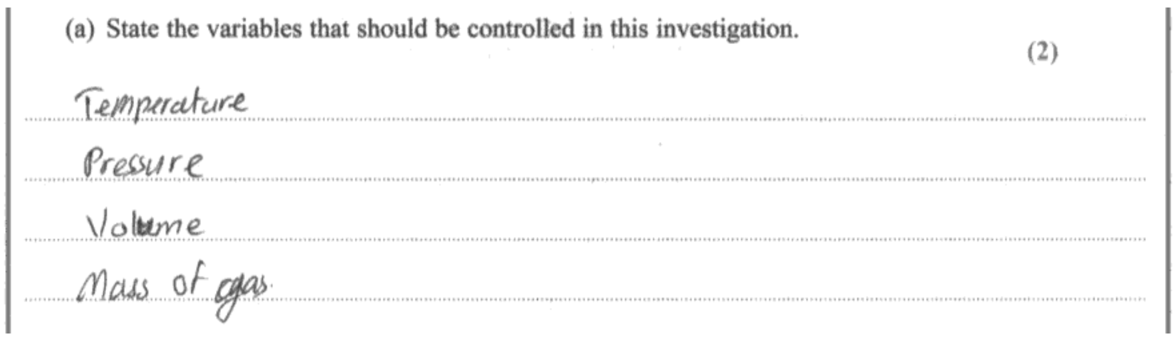
In (b)(i) the time period is only measured over one oscillation and so just 1 mark is awarded here.

In (b)(ii) there is a reference to friction, but on the string rather than the spheres, so it gains just 1 mark for a reference to damping.

In (b)(iii) displacements are read off the graph and amplitudes calculated, although the conclusion that there is a half-life of 9 s is not worthy of the 3rd mark.

Question 16 (a)

Although a large proportion of candidates scored full marks there was a significant minority scoring just one mark. The temperature mark was the mark awarded most often. Failure to gain the second marking point was largely due to not highlighting that it was the mass of air/gas that needed to remain constant: candidates simply stating that 'mass should be constant'. References to the volume/mass/density/amount of oil were common, as were references to the pressure or the diameter / cross section area of tube being constant. Some candidates clearly do not know and understand control variables because many answers included the volume / length of tube. Some good responses just quoted 'a fixed mass of gas at constant temperature', indicating that they had been taught the conditions quite thoroughly.


(a) State the variables that should be controlled in this investigation.

(2)

Temperature

Pressure

Volume

Mass of gas

ResultsPlus
Examiner Comments

A list of possible variables requiring the examiner to select the correct answer is unlikely to score marks. Both pressure and volume were variables in this experiment, and so their presence in the list negates the marks that would have been awarded for temperature and mass of gas.

ResultsPlus
Examiner Tip

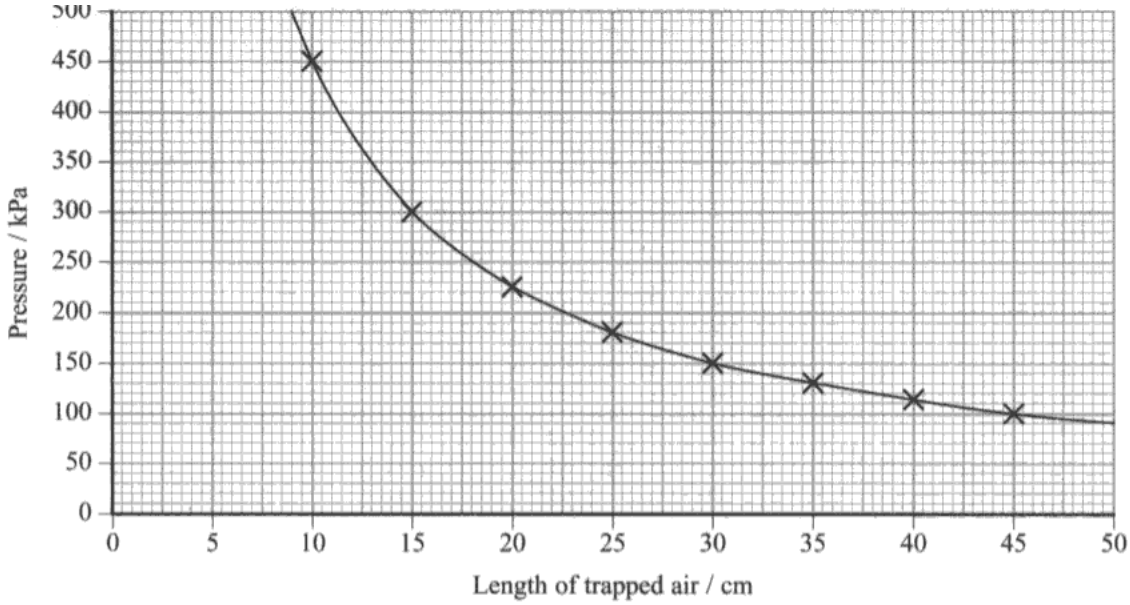
When asked for a specific number of items, make sure that you list only the number required. Incorrect responses will impact upon your overall mark.

Question 16 (b)

This question was not so much about the experiment but about the interpretation of data. This point was not grasped by some candidates, who proceeded to refer to an experiment that they had seen similar to this, giving experimental detail that they had remembered. Focusing instead on the data, it is clear that a numerical method of identifying the relationship is required. There were some good answers that identified the assumption that volume is directly proportional to the length of the trapped gas, that pressure multiplied by the length should be constant and that some numerical values should be taken from the graph to show this and then comments made about the product of them.

Some candidates gained no credit as they simply presented a descriptive answer with no attempt to use the quantitative information supplied. Others noted a few relevant readings from the graph (gaining mp 3), but did not know what to do with them. Some candidates calculated the gradient at one point of the graph, claiming that since this was a negative gradient it showed an inversely proportional relationship. Others simply claimed that since one increased and the other decreased, this showed the relationship was inversely proportional. Responses such as these indicate a basic misconception regarding inverse proportionality which needs to be addressed by teaching.

For those candidates who realised that they had to check that the data provided confirmed the relationship there were some ways of getting close, without gaining full credit. These included stating that pV = k but without stating that 'k' is constant, and stating that two different values of pL gives the same result but without actually doing the calculation for mp 4.



(a) State the variables that should be controlled in this investigation.

(2)

- length of the trapped air

- pressure.

(b) Theory suggests that, for the air trapped in the tube, the pressure p is inversely proportional to the volume V.

Use the graph to show that this relationship is correct. State an assumption that you are making.

when pressure is 450 kPa the length of the trapped air is 10 cm. ~~but~~ and when pressure is 100 kPa the length of the trapped air is 45 cm. This shows that when pressure increases the length decreases. and when pressure decreases ~~10~~ length increasen hence we can conclude that pressure in inversly proportional to volume.

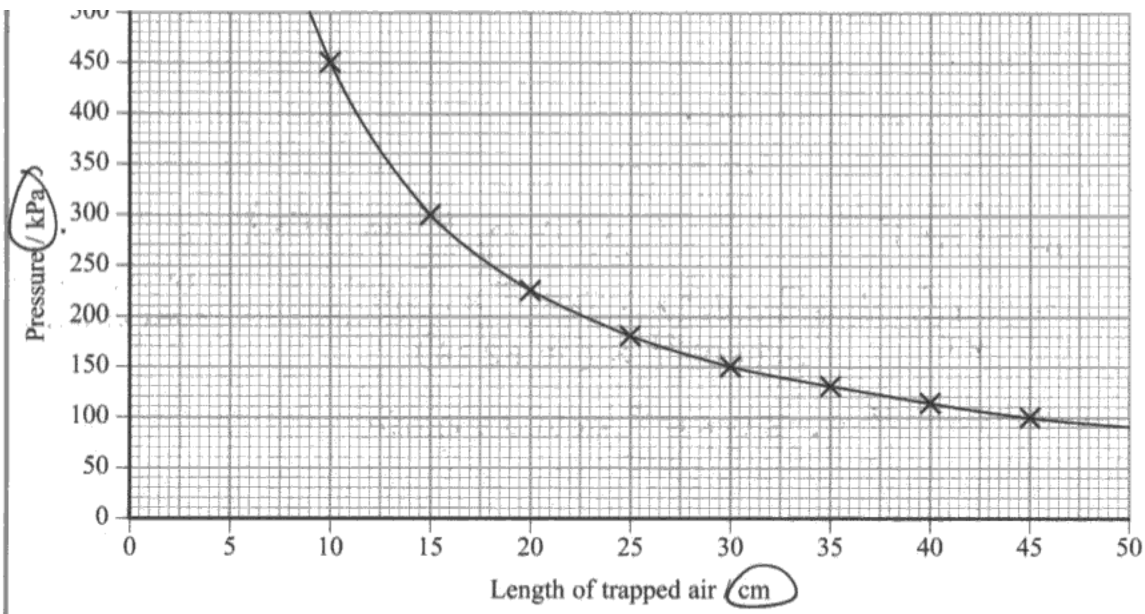
- length of trapped air is ~~eq~~ = volume. (assumption made).

ResultsPlus
Examiner Comments

The candidate has read a pair of values from the graph, although the analysis of the data is weak and so no further marks can be awarded.

ResultsPlus
Examiner Tip

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



(a) State the variables that should be controlled in this investigation. **(2)**

temperature

mass of trapped air (number of moles of gas).

(b) Theory suggests that, for the air trapped in the tube, the pressure p is inversely proportional to the volume V.

Use the graph to show that this relationship is correct. State an assumption that you are making. **(4)**

volume = $\pi r^2 L$ but r constant along tube (assumption)

$\therefore V \propto L$

since $V \propto L$, $p \propto \frac{1}{V}$ can ~~use~~ instead prove $p \propto \frac{1}{L}$

$\therefore p = \frac{k}{L}$ where k is a constant.

L = 10cm, P = 450 kPa
$\therefore$ LP = 4500 kPa cm

L = 30cm, P = 150 kPa
$\therefore$ LP = 4500 kPa

pL = k. at any point on the graph.

L = 15cm, P = 300 kPa
$\therefore$ LP = 4500 kPa cm

$\therefore$ true at any given point on the graph

$\therefore p \propto \frac{1}{L}$ $\therefore p \propto \frac{1}{V}$ $\therefore$ correct.

ResultsPlus

Examiner Comments

This is a good response worth all 4 marks.

Question 16 (c)

Most candidates could convert celsius in to kelvin and were able to identify that the ideal gas equation is needed for this question. However, there were cases where the candidates did not convert the values from the graph in to the correct units (e.g. instead of 45 kPa they used 45 in the equation or instead of converting the length into metres they use the length value in cm as obtained from the graph).

(c) On the day that the investigation was carried out, the temperature in the laboratory was 20 °C.

Calculate the number of air molecules trapped in the tube.

cross-sectional area of tube = 7.5×10^{-5} m^2

(3)

~~$pV = Nkt$~~ $PV = NkT$

~~$\frac{300 \times 15}{1.38 \times 10^{-23} \times 20} = N$~~ $\frac{300 \times 15 \times 7.5 \times 10^{-5}}{1.38 \times 10^{-23} \times 20} = N$

~~N=~~ $N = 1.22 \times 10^{-19}$

ResultsPlus
Examiner Comments

The candidate has left the temperature in celsius, and so is awarded just 1 mark for "use of the equation".

ResultsPlus
Examiner Tip

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

Question 16 (d)

In this question many candidates referred to the pressure and temperature and, in most cases, correctly stated the relationship between pressure and temperature. However, they often failed to mention what happens to the graph.

(d)(i)

This was generally well answered, with many candidates recognising that there would be no change in the graph. Some candidates wrote about the gradient of the graph changing, or the graph shifting to the left/right and so lost out on the mark.

(d)(ii)

This was poorly answered with only a small proportion scoring full marks. Those that scored one mark did so from mp 2. Here some candidates discussed the graph stretching and surprisingly there were some who thought that the graph would shift down or shift to the left. Many candidates did not realise that the P and V would increase in proportion to one another so many references seen to the gradient of the graph. Sketched graphs usually helped candidates to score the marks.

(d) State how the graph would change if

(i) the air molecules in the tube were replaced by the same number of molecules of hydrogen gas.

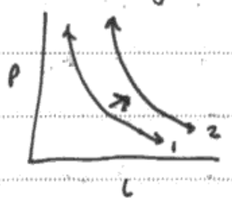
(1)

It would not, as $PV = k$, a constant $= NkT$, none of which would change. If the constant does not change the graph will not change

(ii) the temperature of the laboratory was substantially higher.

(2)

If our T value was larger, then $P_2V_2 > P_1V_1$ (as the constant is greater), so the graph would be moved outwards.



ResultsPlus

Examiner Comments

This response is worth full marks for each part.

(d) State how the graph would change if

(i) the air molecules in the tube were replaced by the same number of molecules of hydrogen gas.

(1)

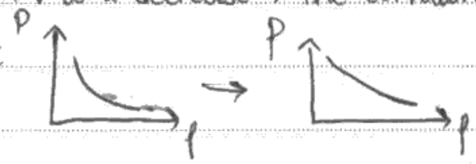
It would not change

(ii) the temperature of the laboratory was substantially higher.

(2)

→ Temperature would increase (PV = nRT)

→ PV = n·k·T ; Temperature ↑; PV will decrease ⇒ The curvature of the graph would be smaller , i.e



ResultsPlus
Examiner Comments

This response scores 1 mark for part (i), but the graphs in part (ii) are not clear enough for marks to be awarded.

(d) State how the graph would change if

(i) the air molecules in the tube were replaced by the same number of molecules of hydrogen gas.

(1)

· less volume so pressure values would be higher for lower length values

(ii) the temperature of the laboratory was substantially higher.

(2)

· values of p and V would both be much higher, but the curve would remain the same shape

ResultsPlus
Examiner Comments

This is a typical response in which references to pressure, rather than the graph, are given. There is 1 mark for part (ii) for identifying that the shape of the curve remains the same.

ResultsPlus
Examiner Tip

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

Question 17 (a)

(a)(i)

Most candidates recalled the reverse direction of the temperature scale. However, remarkably few remembered that it is a log rather than a linear scale and even fewer managed to produce a log scale with the temperature of the Sun in an appropriate position on the scale. Lack of care was a common reason for a mark being lost, with scales in which doubling of T values were seen but matched with very uneven spacing of tick marks.

A small number of candidates thought that "Complete a suitable temperature scale" meant write "Temperature /K" on the horizontal axis.

(a)(ii)

This was the first time the life cycle of a star related to the HR diagram has been set. Although there were some good concise responses seen, some candidates gave long, rambling and disorganised answers. In extended answer questions of this type, candidates need to plan out carefully what they want to say.

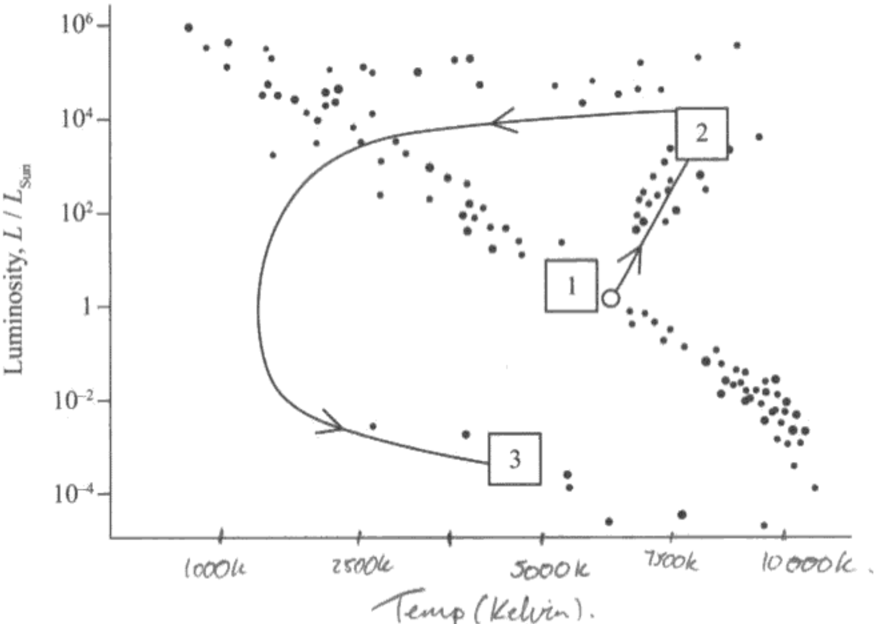
Many candidates scored only mp 1 (hydrogen fusion), mp 4 (expansion to Red Giant) and mp 9 (white dwarf), demonstrating they understood the three key stages in the life cycle of the sun. However, these three points are little more than we might expect from their GCSE work. Specification point 131 is clear that candidates should be able to use the HR diagram to explain the life cycle of stars, whereas many answers seen were little more than descriptions.

Candidates often stated that when hydrogen fusion ceases collapsing takes place, but they did not refer to the process taking place in the core. In fact, few candidates were able to gain the marks for stating what happens in the core of the star at various stages. Some mixed up the progression with that of a supergiant and talked about fusion of elements up to iron. Many seemed to think that the white dwarf would end as a neutron star or a black hole.

Some candidates simply described the H-R diagram, eg. "In position 1, the temperature is about 5800 and luminosity about 1. Then, it moves to area 2 where the temperature is 3000 and luminosity about 10,000. Then, it moves to area 3..." Such responses scored very few marks.

17 The Sun has a surface temperature of 5800 K and is approximately 4.5 billion years old.

The Hertzsprung-Russell diagram maps the future evolution of the Sun, from its current position in area 1 of the diagram, through to its final position in area 3 of the diagram.



(a) (i) Complete a suitable temperature scale on the x-axis.

(2)

*(ii) Use the diagram to describe the lifecycle of the Sun starting from its present position in area 1 and concluding in area 3.

(6)

The sun is in the main sequence will continue to do so for another 5 billion years. fusing hydrogen to helium It will expand & get hotter becoming a red giant it will continue to expand & fusion will continue to occur, until the gravitational weight is greater than the outward pushing force of the nuclear reactions. The star will then contract greatly. & cool down as the reactions slow down. As it is small & cooler it is a white dwarf & will eventually 'die'.

ResultsPlus
Examiner Comments

In part (i) the scale is neither reverse nor logarithmic.

In part (ii) there is a mark for identifying that the Sun will expand to form a red giant star, and a mark for stating that it will end its life as a white dwarf star. The reference to fusion is ambiguous, as the response states that helium is being fused into hydrogen. The arrow between hydrogen and helium may mean that these are to be reversed, but this is not a clear way to indicate this.

ResultsPlus
Examiner Tip

Use technical language carefully in answering questions such as this.

- The sun has been in area 1 for about 5 billion years. After about another 5 billion years, the sun would become a red giant ~~and move to area 2~~. Now the sun would have a lower temperature and higher luminosity.
- After staying in this position for about 10 million years, the sun would lose about 50% of its mass ~~and 2 move to~~ and become a dwarf. This would go on cooling ~~to~~ slowly and eventually 'die' out.

ResultsPlus
Examiner Comments

Part (i) scores 1 mark for a reverse temperature scale.

Part (ii) is very descriptive and is just about worth 1 mark for the reference to the Sun ending its life as a dwarf star.

ResultsPlus
Examiner Tip

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

Presently, hydrogen nuclei are fused within the core of the sun to form helium. When the hydrogen runs out, fusion will stop and the temperature drops, The core contracts and the outer layers expand forming a red giant so the sun moves to position 2.
The high pressure within the contracted core causes fusion of helium to form higher elements leading to an increase in temperature. When helium runs out, fusion stops and the temperature of the core drops again. The core contracts ~~and outer layers expands~~ and an explosion caused by very high pressures creates a planetary nebula. ~~as~~ The temperatures increase during this explosion and the small dense core remains forming a white dwarf as in position 3.

ResultsPlus

Examiner Comments

In part (i) the temperature scale is a reverse scale, but it is linear rather than logarithmic, so only 1 mark here.

In part (ii) the candidate scores 2 marks for each section, scoring 6 marks in total. Although some detail is missing, the description is clear and logical with most essential detail included.

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 17 (b) (i)

Many candidates correctly stated that a **very** high temperature was required to overcome the repulsive force between nuclei/protons. References to overcoming electrostatic forces but not what the forces apply to was quite a common omission. Another error was to refer to atoms (or even molecules,) or sometimes isotopes or neutrons fusing. Few candidates stated that **very** high density/pressure was required to give a sufficient collision **rate**.

(b) The energy source for the Sun is the fusion of light nuclei to heavy nuclei. In its present stage of evolution hydrogen is being converted into helium in the core of the Sun.

(i) State and explain the conditions necessary for fusion to occur in a star. **(3)**

High temperature to overcome electrostatic ~~repulsive~~ repulsive forces between the neucleus of ~~hydrogen atoms~~ atoms fusing. High pressure so that the there are more collisions between the atoms.

ResultsPlus
Examiner Comments

This response is worth 1 mark. The temperature and pressure are only identified as being "high", and the collision rate is not referred to, only the number of collisions.

Hydrogen atoms should be present as 4 H fors one Helium atom $^4_1H \rightarrow ^4_2He + 2\,^0_1n + 2\nu + 2\gamma$. The pressure and temperature should be really high for this splitting and forming to occur as this is a proton proton repulsive force and needs to be overcome.

ResultsPlus
Examiner Comments

The first two marking points are included in this response. There is no reference to collision rate, and so a third mark cannot be awarded.

Question 17 (b) (ii)

Most candidates knew how to answer this part and were able to obtain the expected answer. Calculation errors were surprisingly rare considering the nature of the numbers involved. However, some candidates thought that the values were in atomic mass units and proceeded to use the conversion factor to attempt to bring them to kg. Another common error was omitting the power of ten given in the table (x 10^{-27}) and hence getting an incorrect final answer.

(ii) In a star the fusion of hydrogen into helium takes place in a number of stages. The final stage is:

$$^{3}_{2}He + ^{3}_{2}He \rightarrow ^{4}_{2}He + 2 \times ^{1}_{1}H$$

Calculate the energy released in MeV when one nucleus of the normal isotope of helium is produced.

(4)

Isotope	Mass / 10^{-27} kg
^{3}He	5.008238
^{4}He	6.646483
^{1}H	1.673534

3He ⇒ 5.008238×10^{-27} kg

$E = mc^2$.

$= 5.008238 \times 10^{-27} \times (3 \times 10^8)^2$

$= \dfrac{4.507407 \times 10^{-10} \text{ J}}{10^6 \times 1.6 \times 10^{-19}}$

$= 2817.13$ MeV

1ev = kg · 1.6×10^{-19} J.

4He ⇒ $E = mc^2$

$= 6.646483 \times 10^{-27} \times (3 \times 10^8)^2$

$= \dfrac{5.9818347 \times 10^{-10}}{10^6 \times 1.6 \times 10^{-19}}$

$= 3738.65$ MeV.

1H ⇒ $E = \dfrac{1.673534 \times 10^{-27} \times (3 \times 10^8)^2}{10^6 \times 1.6 \times 10^{-19}}$

$= 941.36$ MeV

$2 \times 2817.13 - (3738.65) - 2(941.36)$

⇒ 12.89

Energy released = 12.89 MeV

ResultsPlus
Examiner Comments

This is an unusual way to calculate the required answer, in which each mass has been converted into an energy equivalent. The final answer is correct and the response gains full marks. However, the candidate has made more work for themselves than necessary, and may have risked arithmetic errors creeping into the calculation.

ResultsPlus
Examiner Tip

Think through the calculation before you start.

Energy = mass deficit.

$\therefore E = (5.008238 \times 2) - (6.646483 + 2 \times 1.673534)$

$= 0.022925 \times 10^{-27}$ kg.

$\therefore \frac{0.022925}{1.66} \times 931.5$

$= 12.864$ MeV.

Energy released = 12.864 MeV

ResultsPlus
Examiner Comments

This response scores full marks, since the candidate has calculated a mass difference in kg and then converted it into atomic mass units before using the energy equivalent of 1 u to obtain the correct final answer.

Although the answer is correct the method is not recommended, since it relies upon conversion factors that are not provided for this specification.

ResultsPlus
Examiner Tip

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

mass before = $(2 \times 5.008238)u = 10.016476\ u$

mass after = $(6.646483 + 2 \times 1.673534)u = 9.993551\ u$

$\Delta m = 10.016476u - 9.993551u = 0.022925\ u$

$\Delta E = \Delta mc^2$

$= (0.022925 \times 1.66 \times 10^{-27})(3 \times 10^8)^2$

$= 3.42 \times 10^{-12}$ J

= ~~21.4~~ 21.4 MeV

Energy released = 21.4 MeV

ResultsPlus

Examiner Comments

This response shows a mass difference calculation together with an energy calculation and a conversion to MeV. The candidate has not read the table heading and has assumed that the masses are given in atomic mass units. Hence the factor of 1.66 in the energy calculation.

ResultsPlus

Examiner Tip

Always check the units for quantities that you are given in a question.

Question 18 (a) (i)

Most candidates were able to show that the decay constant was close to the stated value. However, after correctly calculating a value for λ some candidates went on to use the exponential decay equation instead of A = -λN. A number of responses showed a lack of care in performing calculations with rounding errors leading to poor final values. A small proportion of candidates lost the final mark due to omitting the units.

18 On 1st November 2006, the former Russian spy Alexander Litvinenko fell ill. Twenty one days later he died from the radiation effects of polonium-210. Experts suggest that as little as 0.89 μg of polonium-210 would be enough to kill, although Mr Litvinenko's death was linked to a much larger dose of the radioactive isotope. Traces of the isotope were later found in washrooms at five locations around London visited by the Russian.

Polonium-210 has a half life of 138 days.

(a) (i) In a 0.89 μg sample of polonium-210 there are 2.54×10^{15} atoms of polonium. Show that the decay constant for polonium-210 is about $6 \times 10^{-8}\ s^{-1}$, and hence calculate the activity of a sample of this size.

(4)

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

$= \ln 2 / 138 \times 24 \times 60 \times 60$

$= 5.8 \times 10^{-8}\ s^{-1}$

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

$= 2.54 \times 10^{15} \times e^{-(5.8 \times 10^{-8} \times 1.2 \times 10^{7})}$

$= 1.3 \times 10^{15}$

Activity = 1.3×10^{15}

ResultsPlus
Examiner Comments

Although the decay constant has been correctly calculated, the exponential decay equation rather than the activity equation has been used. In total this response gains 2 marks, since the substitution of data in the second part of the question has been made into an inappropriate equation.

$t_{1/2} = 138$ $\qquad A = -\lambda N$ $\qquad \lambda = \frac{\ln 2}{t_{1/2}}$

$\lambda = \frac{\ln 2}{138 \times 24 \times 3600} = 5.81 \times 10^{-8}\ s^{-1}$

$A = -(5.81 \times 10^{-8})(2.54 \times 10^{15})$

$A = 147661184.8$

Activity = 147661184.8

ResultsPlus
Examiner Comments

This scores 3 marks.

The "show that" is done perfectly - the decay constant is given to more than 1 significant figure with units included (although units are not strictly required for a "show that" since they are given in the question).

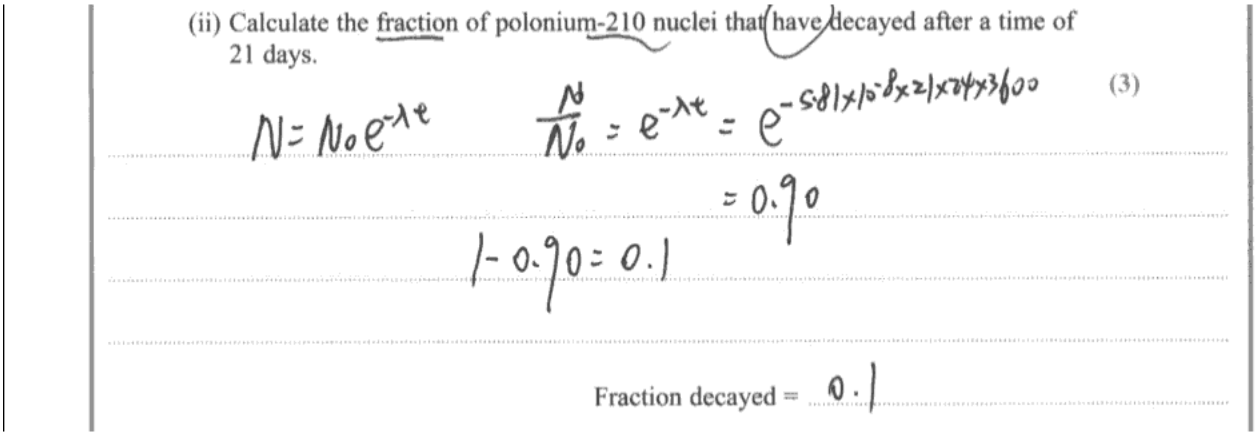
However, the units of the activity (Bq or s^{-1}) are omitted and so, even though the answer is correct, this part only scores 1 mark.

ResultsPlus
Examiner Tip

Know the standard SI units for all commonly met quantities.

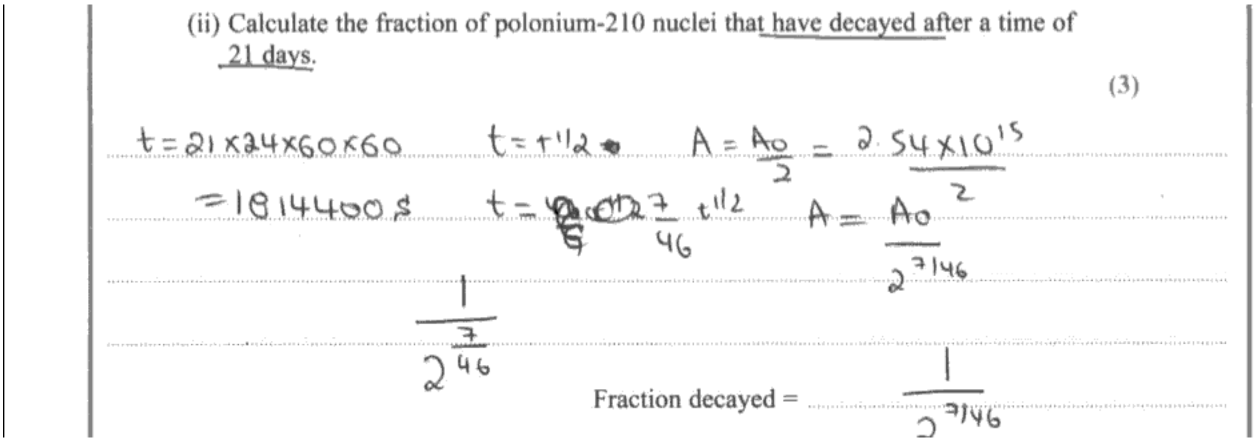
Question 18 (a) (ii)

Candidates who used the exponential decay equation were generally successful. A number of candidates gave a final answer of 0.9 instead of 0.1, confusing the fraction of nuclei decayed with those undecayed. The question asked for the fraction of nuclei that have decayed. An answer rounding to 0.1 or 10% was expected, although an answer of 1/10 was acceptable. Some candidates gave their answers as fractions such as 25/254, which are effectively answers which have not been fully worked out.



ResultsPlus
Examiner Comments

This answer scores full marks.



ResultsPlus
Examiner Comments

This is an unusual, but correct, response in which the fraction of nuclei remaining is calculated. The final answer (0.9) is not fully worked out, and the candidate has forgotten to subtract this from 1 to find the fraction that has decayed. The response is worth 1 mark.

ResultsPlus
Examiner Tip

Always complete calculations fully.

Question 18 (b)

Most students correctly recalled the fact that alpha particles cannot penetrate skin for mp 1. Some candidates only referred to the range in air or alpha particles being stopped by paper, and did not apply this to the case in question.

In contrast, mp 2 was only rarely gained because answers were too vague. Candidates often mentioned cell damage without any reference to ionisation or energy transfer, or stated that internal organs or soft tissue, rather than cell damage, could occur. Nearly all of those credited with mp 2 referred to ionisation and not energy.

> (b) Polonium-210 emits alpha particles. Explain why polonium-210 is virtually harmless unless it is taken into the body.
>
> (2)
>
> This is because α particles have a very short range in air, ~~go its~~ no and they are shield by paper.

ResultsPlus
Examiner Comments

Although the comments made are correct, they do not relate to this particular application.

ResultsPlus
Examiner Tip

Always relate your answers to the context in which the physics occurs.

> (b) Polonium-210 emits alpha particles. Explain why polonium-210 is virtually harmless unless it is taken into the body.
>
> (2)
>
> alpha partiles cannot radiate through the skin, but if they enter the body are very ionising.

ResultsPlus
Examiner Comments

This response comes close to gaining the mark for the idea that alpha particles are unable to penetrate the skin. However, the choice of wording ("radiate") gives the impression that it is the alpha particles that are radioactive. For this reason mp 1 is not awarded. Once again, the candidate comes close to gaining mp 2, but to gain credit here it needed to be clear what would be ionised once the alphas were inside the body.

ResultsPlus
Examiner Tip

Know and use technical words correctly.

Question 18 (c)

(c)(i)

Candidates answered this question very well, with nearly all scoring full marks.

(c)(ii)

This part was quite poorly answered with the most common incorrect response being to do with repulsion between like charges. Candidates should understand that the nucleus recoils as a result of momentum being conserved at the instant of the decay. The repulsion of the two charged particles subsequent to the decay is a separate mechanism. Another incorrect response seen was that lead is unstable, or that the lead recoils to become more stable which may indicate a misunderstanding of the word "recoil".

(c) (i) Complete the equation below for the decay of polonium.

(2)

$$^{210}_{84}\text{Po} \rightarrow {}^{206}_{82}\text{Pb} + {}^{4}_{2}\alpha$$

(ii) State why the Pb nuclei would recoil from the alpha particles emitted during the decay.

(1)

Both nuclei contain positive charges so they repel

ResultsPlus
Examiner Comments

Part (ii) is an example of a common wrong answer. The nuclei move apart as a result of the energy given out in the decay, but the repulsion of the two nuclei happens after the decay.

ResultsPlus
Examiner Tip

Try to relate questions to theory relevant to the context.

(c) (i) Complete the equation below for the decay of polonium.

(2)

$$^{210}_{84}\text{Po} \rightarrow {}^{206}_{82}\text{Pb} + {}^{4}_{2}\alpha$$

(ii) State why the Pb nuclei would recoil from the alpha particles emitted during the decay.

(1)

this is because momentum must be conserved as initial momentum is zero they must travel in opposite directions.

ResultsPlus Examiner Comments

This is a good answer that scores all 3 marks.

ResultsPlus Examiner Tip

Always base your explanations on physical principles.

(c) (i) Complete the equation below for the decay of polonium.

(2)

$$^{210}_{84}\text{Po} \rightarrow {}^{206}_{82}\text{Pb} + {}^{4}_{2}\alpha$$

(ii) State why the Pb nuclei would recoil from the alpha particles emitted during the decay.

(1)

A Large amount of energy is given out along with the Pb nuclei and alpha particles.

ResultsPlus Examiner Comments

The response identifies that a large amount of energy is given out in the decay, but does not relate this to the energy being shared between the particles and momentum being conserved.

Question 18 (d)

Most candidates were able to give the correct meaning of 'random', although lack of precision was sometimes a problem, with references to 'it' or isotopes, or even molecules decaying. Many candidates were unable to explain 'spontaneous', not realising that it meant the decay cannot be influenced by external factors. A number of candidates thought it meant the same as random but with different wording.

(d) Radioactive decay is said to occur spontaneously and randomly. Explain what is meant by spontaneous and random in this context.

(2)

Spontaneous This means that radioactive decay is not affected by chemical changes in the environment or physical conditions such as temperature.

Random This means that it is impossible to predict when a particular nucleus will decay next.

ResultsPlus

Examiner Comments

This response says enough to score 2 marks.

(d) Radioactive decay is said to occur spontaneously and randomly. Explain what is meant by spontaneous and random in this context.

(2)

Spontaneous It means it occurs naturally, scattering the radiation ~~to~~ in different angles. Therefore it is said to be spontaneous.

Random It means there is no fixed time for radioactive decay to occur. It just happens randomly.

ResultsPlus

Examiner Comments

Neither spontaneous nor random is correctly explained, so this response scores no marks.

ResultsPlus

Examiner Tip

Learn the definitions of standard terms that occur in the specification.

(d) Radioactive decay is said to occur spontaneously and randomly. Explain what is meant by spontaneous and random in this context.

(2)

Spontaneous We donot know when an ~~partic~~ atom may decay.

Random We could only predict the chance of a nucleus decaying so cannot tell exactly when it will decay.

ResultsPlus

Examiner Comments

This response is quite typical of many seen. Spontaneous and random are described using slightly different wording that amounts to the same thing. The explanation of what is meant by random gains 1 mark.

Question 18 (e)

Quite a few candidates assumed that Litvinenko had just touched the isotope to become contaminated, hence their responses referred to the isotope being on hands or clothes and being transferred by touch rather than the idea of it leaving the body via excretion. Many candidates realised that the isotope would be excreted from the body, although there were some unusual references to contamination from nuclear power plants. Also many realised that the half life was such that the activity would be detectable for some time after the event. Failure to qualify that the long half-life meant that it was still detectable was a common reason for mp 2 not being awarded. It was alarming to read ideas that some candidates had that the alpha particles remained around as "radioactivity". Some candidates wrote explanations that had little to do with the question, and statements such as "Russians handle nuclear weapons", references to background radiation, or to the smoke detectors in the washrooms were not uncommon.

(e) Suggest why traces of the isotope were found in locations visited by the Russian.

(2)

because it ionises the places where the Russian visited so it would show traces where the Russian had been.

ResultsPlus
Examiner Comments

This response is typical of many incorrect suggestions that neither established that traces of the isotope had been excreted from Litvinenko nor referred to the relatively long half life of the isotope. No marks awarded.

→ The isotope has a very long half life and therefore a very low decay constant (hence still found in the places)
→ Since the russian was exposed to the isotope, he must have handled it with his bare hands and carried it around. traces could also be present in his urine.

(Total for Question 18 = 16 marks)

ResultsPlus
Examiner Comments

This response gains full marks. The first mark (for traces of the isotope being excreted from the body) is almost not awarded, since the candidate begins by talking about Litvinenko handling the source with his bare hands. However, the candidate goes on to refer to traces of the isotope in Litvinenko's urine, which is enough to establish that Litvinenko was excreting the isotope.

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.

Grade Boundaries

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

http://www.edexcel.com/iwantto/Pages/grade-boundaries.aspx

Llywodraeth Cynulliad Cymru
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