Pearson

Edexcel

Examiners' Report
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IAL Physics WPH15 01

ResultsPlus

Introduction

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

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

The paper includes the use of specific command words as detailed in the specification, Appendix 9: Taxonomy. It is recommended that centres ensure that their candidates understand what is required when responding to such questions.

In questions in which the command word was deduced, evaluated, or assessed, the final mark could sometimes not be awarded on otherwise good responses because a final appropriate comment was missing.

Candidates should be encouraged to read questions carefully to ensure that their responses take into account all the relevant information.

Section B questions are set in context. Candidates should be aware that the context of the physics in which the question is set and all supplementary information provided are essential for a complete response that could gain full marks.

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

Question 11

This question was poorly answered. Many candidates seemed quite confused about the concept of gravitational potential, and references to gravitational field strength were quite often seen.

Many candidates could say that the gravitational potential gets less as distance increases, but essential detail was usually omitted. Those responses which did try to apply a knowledge of gravitational potential often lacked clarity, and reference to X, Y or Z were often absent.

As $V_{grav} = \frac{-Gm}{r}$ potential is inversely propertional to the radius. It is not directly propertional to the radius.
The greater radius will have less increase in potential when the radius increase.
So the space is increasing.

ResultsPlus
Examiner Comments

This response clearly indicates that gravitational potential is inversely proportional to the distance from the Earth (radius). The idea that the equipotential lines get further apart as the radius increases is also included and so this response gains both marks.

Note that the response states that the potential is increasing as radius increases. This is correct, as although the magnitude of the potential gets smaller the potential becomes less negative.

Question 12

The vast majority of responses scored full marks on this item. Those responses that did not achieve full credit often missed out of MP3 by omitting the unit. Another common error was an incorrect final value due to not squaring *r*.

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

$$= \frac{6.67 \times 10^{-11} \times 3.40 \times 10^{21}}{(7.88 \times 10^{5})^2}$$

$$= 0.365$$

$$W = mg$$

$$= 210 \times 0.365$$

$$= 76.7$$

Weight = 76.7 N

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Examiner Comments

This response shows a full solution leading to a correct final value with units and so all 3 marks are awarded.

Given $G = 6.67 \times 10^{-11}\ m^3/kg s^2$

Mass of Titania $M = 3.40 \times 10^{21}$ kg Mass of the vehicle $m = 210$ kg

Radius of Titania $r = 7.88 \times 10^5$ m

$F = GMm/r^2 = \frac{6.67 \times 10^{-10} \times 3.4 \times 10^{21} \times 210}{(7.88 \times 10^5)^2} = 7.67\,N$

Weight = 7.67N

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Examiner Comments

This response calculates the gravitational force directly, rather than obtaining a value for *g* and then using the weight equation. This is fine, but there is a power of 10 error in the calculation, and so MP3 is not met. It looks as though there is a transcription error as the value of *G* is substituted into the equation. The response scores 2 marks.

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Examiner Tip

Always check substitutions carefully to avoid arithmetic errors in a calculation.

Question 13 (a)

This question was poorly answered. In many responses the discussion centred on density and pressure, with a significant number of responses referring to the density difference between the helium in the airship and the air outside

Upthrust was only referred to in a minority of responses. Those responses which did make reference to upthrust, often revealed major misconceptions as to what this force is. Most candidates could not use the concept of upthrust, or even use the word, as the upward force acting on the airship.

Some candidates had a misconception that the upthrust was caused by the helium gas collisions inside the airship. Another common misconception was that floating is caused by the upthrust being greater than the weight force; not appreciating that if it was, the airship should move upwards rather than float.

The weight is equal to the upthrust, so resultant force on the airship is zero. As a result the airship is able to float.

ResultsPlus Examiner Comments

This response is succinct, but includes all the detail required by the MS, and so scores 2 marks.

Density of helium is less than the density of air, so the upthrust on the airship is greater than the weight, so the resultant force is upwards.

ResultsPlus
Examiner Comments

This is a typical example of a response that does not score any marks. Reference to the densities of air and helium are insufficient to explain why the airship floats. Such responses often went on, as here, to state that the upthrust is bigger than the weight which is incorrect.

In everyday language we may refer to an object that is moving upwards in the air as "floating". However, the scientific definition involves an equilibrium of forces.

Question 13 (b)

The vast majority of responses for this question scored full marks. The final answer was incorrect in some cases due to temperature being left in ^{o}C, or an incorrect constant being used in the pressure equation.

Some attempts to use $pV = nRT$ were seen, although for this approach to yield the correct answer, $N = nN_A$ must also be used. We do not supply values for R or N_A in the data sheet supplied with the question paper.

The equation supplied for this specification is $pV = NkT$, which was used correctly in most responses, but occasionally the electrostatic constant k (= $1/4\pi\varepsilon_0$) rather than the Boltzmann constant was used.

$pV = NkT$.

so $1.08 \times 10^5 \times 7020 = N \times 1.38 \times 10^{-23} \times (25 + 273)$

$N = 1.84 \times 10^{29}$.

so $m = 1.84 \times 10^{29} \times 6.64 \times 10^{-27}$

$= 1222$ kg.

Mass of helium gas = 1222 kg

ResultsPlus
Examiner Comments

All stages are clearly set out. The final answer is correct and units are included, so this response scores full marks.

$m = N \times$ mass of helium atom

$pV = NkT \qquad T = 25 + 273 = 298\,K$

$N = \frac{pV}{kT} = \frac{1.08 \times 10^5 \times 7020}{1.38 \times 10^{-23} \times 298} = 1.844 \times 10^{29}$ molecules

~~$m = 1.844 \times 10^{29} \times 6.64 \times 10^{-27} = 1224.15\,kg$~~

$m = \frac{M_a}{N} = \frac{6.64 \times 10^{-27}}{1.844 \times 10^{29}} = 3.6 \times 10^{-56}\,kg$

Mass of helium gas = ~~1224.15 kg~~ $3.6 \times 10^{-56}\,kg$

ResultsPlus
Examiner Comments

This response correctly calculates a value for the number of molecules, so MP1 and MP2 are met. However, there is a muddle between the mass of the gas and the mass of a molecule, and so no further credit is gained and the response scores 2 marks.

Question 14 (a)

Most correct responses referred to lead absorbing alpha radiation, with a small number stating that the air gap between the source and the detector would stop the alpha radiation. However, a minority of responses that just stated that paper absorbs alpha radiation did not score the mark, as there is no paper reference in the set up given in the question.

because alpha cannot penetrate the sheets of lead .

alpha ~~rr~~ particles have a short range .

ResultsPlus
Examiner Comments

The first sentence in this response gains the mark. The reference to alpha particles having a short range does not add anything in this case.

Alpha radiation ~~gets~~ can be stopped with skin or paper.

ResultsPlus
Examiner Comments

The statements made in this response, do not take into account the context of the question. The diagram shows lead sheets (and a small air gap) between the source and the detector, and so reference must be made to either of these materials for a mark to be awarded.

ResultsPlus
Examiner Tip

Always frame your response in the context given in the question.

Question 14 (b)

Most candidates scored at least 1 mark for this item, stating a correct method to make the experiment more accurate. However it was rare to see a reference to systematic error, or percentage uncertainty.

As a general rule, in a question that requires an explanation of how an experiment can be carried out more accurately, part of the response should be to state the type of uncertainty that will be reduced for the suggested action.

~~Measure~~ Remove the source and measure the background count for 2 minutes. Substract this value from the count she recorded with source present for 2 minutes, and then calculate count rate by dividing by 120. The background radiation would result in the ~~measured~~ count rate ~~measured~~ calculated being greater than the true value. This method would reduce systematic error.

ResultsPlus Examiner Comments

This response describes how the background count rate should be determined and goes on to state that background count rate introduces a systematic error. Both marks are awarded.

She should find the background count rate and subtract it from the count rate for a more accurate value.

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Examiner Comments

This response scored MP1 but not MP2. Instead of referring to systematic error or the count rate being overestimated (due to background count), the response simply repeats the wording, "a more accurate value", given in the question.

Question 14 (c)

Most responses to this question scored at least 2 marks. It might be expected that candidates would know that μ and x should have complementary units. However, many responses in which the correct value of μ was seen did not include a unit.

In many responses it was assumed that μ is the gradient of the curve. A tangent drawn at some random point on the graph could score MP1, although since in many cases values were read from a point off the curve, this was only rarely the case.

$$\mu = -\left(\frac{\ln R - \ln 60}{x}\right)$$

$$= \frac{-(\ln(36) - \ln(60))}{(1.5 \times 10^{-2})} = 34 \text{ m}^{-1}$$

$\mu =$ 34 m^{-1}

ResultsPlus
Examiner Comments

This response was the method leading to the correct answer seen most often. Values are read from the graph and substituted into the equation. The answer is within range and includes units, and so all 3 marks are scored.

$R = 60e^{-\mu x}$ => $\ln R = -\mu x + 60$ is similar to $y = mx + c$. so gradient $= -\mu$.

gradient $= -\mu = \frac{\Delta y}{\Delta x} = \frac{36s^{-1} - 31s^{-1}}{0.015m - 0.02m} = -1000m^{-1}s^{-1}$

=> $\mu = 1000 m^{-1}s^{-1}$

$\mu =$ 1000 $m^{-1}s^{-1}$

ResultsPlus
Examiner Comments

This response was a common way not to obtain the correct answer. A tangent is drawn to the curve, but at the wrong point on the graph. Values are read from the curve, and so MP1 is given. The gradient calculation is invalid. The answer is out of range, as well as the units being incorrect, so just 1 mark for this response.

Question 15 (a)-(b)

Most responses seen to part (a) were good. In some cases careless errors, such as not expressing the calculated value to the correct number of significant figures, meant that the final mark was not awarded.

In a minority of responses either a latent heat calculation or a specific heat capacity calculation was carried out, rather than both calculations.

A variety of approaches were seen for responses to part (b). In some responses 44% was used rather than 56% to find the intensity at sea level. Some candidates failed to complete their response with a full comparison of both values.

Those responses that had more major errors in their analysis included confusion between energy and power values, use of astronomy equations (including the equation from Stefan's law); with a few candidates even trying to apply radioactive decay equations. Some candidates struggled to calculate the area, with attempts of using the equation for the area of a circle being surprisingly common.

$(3.53 \times 10^5) \times (2.09 \times 10^3) \times (18)$

$E = 1.328 \times 10^{10}$

$1.328^{10} + [(3.53 \times 10^5) \times (3.36 \times 10^5)]$

$= 1.32 \times 10^{11}$ J

100 − 44 = 56%

$\frac{56}{100} \times 1370 = 767.2\ Wm^{-2}$

~~385~~ V = surface area × thickness

∴ surface area = $\frac{385}{0.85} = 452.9\ m^2$

$I = \frac{L}{4\pi d^2}$ → L = power = 767.2 × 452.9

= 347 464.9

power × time = E

$t = \frac{1.32 \times 10^{11}}{347464.9}$ = 379 894.5 s

days = $\frac{379894.5}{8.64 \times 10^4}$ = 4.39 → 4 days

claim is wrong as it will take less than 7 days.

ResultsPlus
Examiner Comments

This response sets out the solution to both parts clearly. The answer to (a) is given to 3 significant figures, which is sufficient, and the answer to (b) includes units as well as a full comparison, so full marks for each part.

$H = 2.09 \times 10^3 \times 3.53 \times 10^5 \times 18$

$= 1.33 \times 10^{10}$ J

$H = 3.36 \times 10^5 \times 3.53 \times 10^5$

$= 1.19 \times 10^{11}$ J

1.19×10^{11} J $+ 1.33 \times 10^{10}$ J $= 1.32 \times 10^{11}$ J

$P = 1370 \times \left(\frac{100 - 44}{100}\right)$

$= 767.2 \frac{W}{m^2}$

$385 = 0.85 \times A$

$A = 452.9$ m^2

$P = 767.2 \times 452.9$

$= 347496$ W $= \frac{1.32 \times 10^{11}}{t}$

$t = \frac{379859.97}{8.64 \times 10^4}$

$= 4.4$ days so scientist not true.

ResultsPlus
Examiner Comments

The solutions to both parts of the question are correct. However, there is no comparison given with 7 days in part (b), as the response simply states that the "scientist is not true". MP6 in part (b) is not given, but all the other points in the MS are met.

Question 16 (a)

More than half of the responses seen scored full marks for this question. The most common mistakes were using πr^2 rather than $4\pi r^2$ for the surface area, and omitting the unit for the calculated wavelength.

Some candidates used the equation for the volume of a sphere instead of the surface area of a sphere. Other candidates confused the value of *d* with *r* when substituting into the relevant equations.

Even when other parts of a response were incorrect, Wien's law was usually applied successfully.

radius of ε-Eridani = 5.12 × 10 m

(5)

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

$$1.05\times10^{-9} = \frac{L}{4\pi(9.94\times10^{16})^2}$$

~~1.304 × 10^26 W~~

$$L = 1.3\times10^{26}\ \text{W}$$

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

$$1.3\times10^{26} = 5.67\times10^{-8}\times4\pi\times(5.12\times10^{8})^2\times T^4$$

$$\left(\frac{1.3\times10^{26}}{5.67\times10^{-8}\times4\pi\times(5.12\times10^{8})^2}\right)^{\frac{1}{4}} = T = 5136.33\ \text{K}$$

5136.33

$$\lambda_{max}\times T = 2.898\times10^{-3}\ \text{mK}$$

$$\lambda_{max} = 5.64\times10^{-7}\ \text{m}$$

λ_{max} = ...

ResultsPlus
Examiner Comments

Work is set out clearly, sensibly using the left hand side of the answer space so that the solution could continue on the right hand side. The final answer is correct and units are included and so this response scores full marks.

ResultsPlus
Examiner Tip

Set your work out clearly so that it is easy to follow.

$\lambda_{max} T = 2.898 \times 10^{-3}$ $L = \sigma A T^4$ $I \frac{L}{4\pi d^2}$

$L = 5.67 \times 10^{-8} \times \frac{4}{3} \times \pi \times r^3 \times T^4$ —— ①

$L = 1.05 \times 10^{-9} \times 4\pi \times d^2$

$= 1.05 \times 10^{-9} \times 4\pi \times (9.94 \times 10^{16})^2 = 1.30 \times 10^{26}$ —— ②

$1.30 \times 10^{26} = 5.67 \times 10^{-8} \times \frac{4}{3}\pi \times (5.12 \times 10^{8})^3 \times T^4$

$T^4 = 4078137$

$T = \sqrt[4]{4078137} = 44.9$

$\lambda_{max} = \frac{2.898 \times 10^{-3}}{44.9} = 6.45 \times 10^{-5}$ m

λ_{max} = 6.45×10^{-5} m

ResultsPlus
Examiner Comments

This response leads to an incorrect final value. The surface temperature of 44.9 K should have been a warning that there was an error somewhere. The problem is the use of the expression for the volume of a sphere instead of the expression for the surface area of a sphere in the Stefan equation. Although MP2 is not given, MP3 is given. In addition, the Wien's law equation is used with the calculated value of the temperature and so MP4 is given. Luminosity was correctly worked out and so MP1 is also given. Overall, this response scores 3 marks.

(5)

$\lambda_{max} = \frac{b}{T}$

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

$L = 1.65 \times 10^{26} W$

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

$T = \left(\frac{1.65 \times 10^{26}}{4\pi (5.12 \times 10^{6})^2 \times 5.67 \times 10^{-8}}\right)^{\frac{1}{4}}$

$T = 6.028 \times 10^{3} K$

$\lambda_{max} = 480.8 nm$

λ_{max} = 480.8 nm

ResultsPlus
Examiner Comments

This response score just 2 marks. The value for luminosity is incorrect and, as no substitutions are shown, MP1 is not given. MP2 and MP3 are given, as the expression for the surface area of a sphere is used with other correct substitutions into the Stefan equation. The temperature is incorrect and, as no substitutions are shown, MP4 is not given. The final answer is incorrect, and so MP5 is not given.

ResultsPlus
Examiner Tip

Always show substitutions into the formula, as you will gain the "use of" mark even if your answer is incorrect due to an arithmetic error.

Question 16 (b)

The responses to this item were variable, with less than half of the responses seen scoring full marks. However, most responses included a correct application of the red shift equation and so were able to score MP1 and MP2.

Many candidates used the value of wavelength they found for part (a) instead of 480 nm. Some candidates lost MP3 because they did not compare their answer with the resolution. Units were often missed, as well as poor comparisons. The understanding of resolution used in a practical situation was poor.

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

$$\frac{1.55\times10^{4}}{3\times10^{8}} = \frac{480\times10^{-9} - \lambda_1}{\lambda_1}$$

$\lambda_1 = 4.7998\times10^{-7}$ m $\Rightarrow \Delta\lambda = 2.48\times10^{-11}$ m

$\Delta\lambda = 0.0248$ nm

so $0.0248 < 0.05$ nm

so wont be detected

ResultsPlus
Examiner Comments

This response scores full marks.

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

$\Delta\lambda = \frac{1.55\times10^4}{3\times10^8} \cdot 480\times10^{-9} = 2.48\times10^{-11}$ m

0.05nm $= 5\times10^{-11}$ m

$5\times10^{-11} > 2.48\times10^{-11}$

so yes it can detect this change

(Total for Question 16 = 8 marks)

ResultsPlus
Examiner Comments

This response scores 2 marks. It has a correct calculation and includes a correct comparison, but makes an incorrect conclusion, so does not gain MP3.

Question 17 (a)

This was answered correctly by the vast majority of candidates. Most candidates knew that beta particles have A = 0 and Z = −1 and were able to balance the numbers on either side of the reaction. The most common way to miss out on full marks was to subtract −1 incorrectly from 53.

$$ {}^{131}_{53}\mathrm{I} \rightarrow {}^{131}_{54}\mathrm{Xe} + {}^{0}_{-1}\beta^{-} + {}^{0}_{0}\bar{\nu}_{e} $$

ResultsPlus
Examiner Comments

This is a correct solution which gains both marks.

$$ {}^{131}_{53}\mathrm{I} \rightarrow {}^{130}_{53}\mathrm{Xe} + {}^{1\emptyset}_{0N}\beta^{-} + {}^{0}_{0}\bar{\nu}_{e} $$

ResultsPlus
Examiner Comments

This response muddles A and Z for the beta particle and so neither MP is met.

Question 17 (b)(i)-(ii)

In part (b)(i), the calculation of $t_{½}$ for MP1 and MP2 posed little problem for most candidates although some did not convert half-life in days into half-life in seconds.

Very many responses then went awry. Having seen units of GeV/c^2 many candidates tried to use $\Delta E = c^2 \Delta m$.

In part (b)(ii) the most common mistake was to take 2.35 GBq as A_0 rather than A.

$\frac{122 \times 10^9 \times 1.6 \times 10^{-19} J}{(3 \times 10^8 m/s)^2} = 2.17 \times 10^{-25} kg$

$51.8 MBq kg^{-1} \times 65 kg = 3367 MBq$

$\frac{\ln 2}{t_{\frac{1}{2}}} = \lambda \quad \frac{\ln 2}{(8.02 \times 24 \times 60 \times 60) s} \quad 1 \times 10^{-6} s^{-1} = \lambda$

$A = N\lambda \quad 3367 \times 10^6 Bq = 1 \times 10^{-6} s^{-1} \times N \quad N = 3.37 \times 10^{15}$

$2.17 \times 10^{-25} kg \times 3.37 \times 10^{15}$

$= 7.30 \times 10^{-10} kg$

Mass of ^{131}I required = $7.30 \times 10^{-10} kg$

$\frac{\ln 2}{t_{\frac{1}{2}}} = \lambda \quad \frac{\ln 2}{(8.02) days} = 0.0864 day^{-1}$

$2.35 \times 10^9 Bq = A_0 e^{-0.0864 day^{-1} \times 1 day}$

$\frac{2.35 \times 10^9 Bq}{e^{-0.0864 day^{-1} \times 1 day}} = A_0 \quad A_0 = 2.56 \times 10^9 Bq$

Activity of sample when prepared = $2.56 \times 10^9 Bq$

ResultsPlus
Examiner Comments

This response scores full marks for each part.

$\lambda = \frac{\ln 2}{t_{1/2}}$ ~~$A = \frac{51.8 \times 10^6}{65}$~~

$= \frac{\ln 2}{8.02}$ ~~$= 7.97 \times 10^5$ Bq.~~

$\therefore \lambda = 0.086 \text{ days}^{-1}$.

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

$\Rightarrow A = 51.8 \times 10^6 \times e^{-0.086 \times 8.02}$

$= 2.60 \times 10^7$ Bq kg^{-1}.

Mass of ^{131}I = $\frac{2.60 \times 10^7 \text{ Bq } \cancel{kg^{-1}}}{\cancel{0.5}\ 51.8 \times 10^6 \text{ Bq} \cancel{kg^{-1}}}$ $= (0.502 \times 65)$

$= 32.6$ kg.

Mass of ^{131}I required = 32.6 kg

$A = A_0 e^{-\lambda t}$ $\therefore A_0 = 1.85 \times 10^{10}$ Bq.

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

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

$= \frac{2.35 \times 10^9}{e^{-0.086 \times 24}}$

Activity of sample when prepared = 1.85×10^{10} Bq.

ResultsPlus
Examiner Comments

In the response to (b)(i), a value of decay constant in day^{-1} is calculated, which is fine for MP1. However, in the next stage of the solution the exponential equation is used rather than the equation relating decay to number of unstable nuclei.

In (b)(ii) the solution is correct, but since the decay constant is in day^{-1} the time needs to be in days. However, the time in hours was substituted, and so the final answer is incorrect.

Just 1 mark for each part.

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Examiner Tip

When using the exponential equation for radioactive decay, decay constant and time must be expressed in complementary units.

Question 18 (a)

This question was well answered by most candidates , although almost a quarter of the responses seen did not score full marks. Candidates that did not achieve full credit often made careless mistakes when expressing the algebra involved in the derivation.

$F = \frac{GMm}{r^2}$, $F = m\omega^2 r$

So $F = F$

$\frac{GMm}{r^2} = m\omega^2 r$

$GM = \omega^2 \cdot r^3$

$GM = \frac{(2\pi)^2}{T^2} \cdot r^3$

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

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Examiner Comments

The solution is set out clearly and logically, so all 3 marks are given.

Question 18 (b)(i)-(ii)

Responses to part (b)(i) were generally successful, although some candidates were confused over the value of the mass to use.

A surprising number of candidates were unable to find the correct equation (despite it being given in part (a)), although some went back and effectively rederived the equation.

Calculated values of orbital period were generally accurate. Sometimes the value was not given to the correct number of significant figures. Some candidates omitted the factor of 8.0×10^{11} in their calculation, and some made correct substitutions but obtained an incorrect final answer due to poor calculator execution.

In part (b)(ii) most candidates knew that this was the evidence for dark matter, but many didn't make the full argument using the period values.

Many candidates could compare the calculated period with the actual period, and gave a correct deduction that the actual mass should be greater. They could also guess correctly that dark matter should exist, but often did not go on to explain why it must be dark matter.

Some candidates thought this was about the Doppler effect, leading them into a discussion of recessional velocity, Hubble's law and even the critical density of the Universe.

Total Mass $1.99 \times 10^{30} \times 8 \times 10^{11} = 1.592 \times 10^{42}$ kg

$$\sqrt{\frac{4 \times \pi^2 \times (5.7 \times 10^{20})^3}{6.76 \times 10^{-11} \times 1.592 \times 10^{42}}}$$

$T = 8.242 \times 10^{15}$

$\approx 8 \times 10^{15}$ s //

The time for orbital is smaller than calculated
thus the mass of the galaxy must be more
than 8.0×10^{4} solar masses as radius is (distance)
correct
This suggest there is a possibility of dark matter
in galaxy since it doesn't interact with E-m
radiation it is not easy to detect them and
account for higher mass (M) in orbital time calculation.

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Examiner Comments

Most candidates were able to substitute numbers into the given equation to obtain a correct answer to (b)(i), as is the case here.

In (b)(ii) there is enough detail provided for all of the MP to be awarded.

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

$$= \sqrt{\frac{4\pi^2 \times (5.7\times10^{20})^3}{6.67\times10^{-11} \times 8\times10^{4} \times 1.99\times10^{30}}}$$

$$= 8.29 \times 10^{15}\ s$$

$$\therefore T = 8.3 \times 10^{15}\ s$$

* If there's a difference in the orbital period, it shows that there's a hidden mass in addition to the galaxy mass.
* Such hidden mass is called dark matter.
* It does not emit any electromagnetic radiation.

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Examiner Comments

This response scores 2 marks for each part. In (b)(ii) there is no comparison of the calculated period with the actual period, just a statement that there is a difference. Hence MP1 is not given. Similarly, there isn't a direct reference to the mass being greater than the value given in the stem, so MP2 is not given.

$$T^2 = \frac{4\pi^2 \times (5.7\times10^{20})^3}{6.67\times10^{-11} \times (1.99\times10^{30} \times 8\times10^{11})}$$

$$T = 8.298\times10^{15}\ \text{s}$$

~~This means that the gravitational forces of other celestial bodies may be affecting the value for the orbital period~~ As G is a constant and the numerator of the equation stays the same it is M which is at fault. This could suggest that the solar mass of the universe is different from what the Luminosity suggested.

ResultsPlus
Examiner Comments

This response gains both marks for (b)(i), but no marks for (b)(ii). There seems to be a confusion in what is understood by the solar mass in (b)(ii), which was seen in a range of responses to this question. The solar mass is the mass of the Sun, and is used in this question as a convenient yardstick. This candidate seems to be equating solar mass to mass due to dark matter.

Question 19 (a)(i)-(ii)

Part (a)(i) was very well answered. A small proportion of responses seen included calculation errors, and a few responses were seen in which a wrong value for ‘u’ was used.

Sometimes the final calculated value was not given to a sufficient number of significant figures.

There was a wide variety of possible solutions to part (a)(ii). Many candidates gave their calculations without any explanation, which made their solutions hard to follow.

A significant number of candidates simply applied $\Delta E = c^2 \Delta m$ to 10% of the Sun’s mass used in fusion, and therefore did not draw much credit from this item.

The time calculation was done differently depending on the candidates approach, but many scored well just by following a clear and logical approach. Most candidates found the time it takes for one fusion to take place rather than finding the rate of fusion. Rate of fusion and mass rate did not occur to the majority of candidates.

A consistent conclusion based on calculated values was often omitted.

$M_{deficit} = 4(1.0078) - 4.0026 = \sout{0.00}\ 0.0286\ u$

$= 0.0286 \times 1.66 \times 10^{-27} = 4.7476 \times 10^{-29}\ kg$

$\therefore E = mc^2 = (4.7476 \times 10^{-29})(3 \times 10^8)^2 = 4.27 \times 10^{-12}\ J$

$\approx 4.3 \times 10^{-12}\ J$

3.83×10^{26} J s^{-1} ÷ ($4.\overset{27}{8}\times 10^{-12}$) J He^{-1} = 8.97×10^{37} He s^{-1}

∴ we are using up: 3.5878×10^{38} H s^{-1}

∴ $1.3\overset{9}{8} \times 10^{30} \times 0.1 = 1.39 \times 10^{29}$ kg

∴ m H used per sec = ~~(3.5878)(1.66× 10^{-27} × 1.0078)~~ =

= $(3.5878 \times 10^{38})(1.66 \times 10^{-27} \times 1.0078)$

= 6.0017×10^{11} kg s^{-1}

∴ $\frac{1.39 \times 10^{29}}{6.0017 \times 10^{11}} = 2.316 \times 10^{17}$ s

∴ $\frac{2.316 \times 10^{17}}{3.15 \times 10^{7}} = 7.35 \times 10^{9}$ yrs, the claim is not accurate as it will take less time to use that much Hydrogen

ResultsPlus
Examiner Comments

The response to (a)(i) gains full marks. The correct answer is given to an appropriate number of significant figures.

The response to (a)(ii) is correct and gains all except MP5. The final MP is not given, as the conclusion does not include a full comparison.

ResultsPlus
Examiner Tip

In a question which requires a conclusion to be drawn, be sure to make a direct comparison with relevant data given in the question.

1.0078 x 4 − 4.0026 = 0.0286u

E = 4.7476x10^-29 g x (3x10^8)^2

= 4.27 x 10^-12 J

5 × 10^7 s

(5)

10% of H = 1.39x10^29 = n x 1.67x10^-27

n = 8.323x10^55 H

x 4.27x10^-12 J

8.323x10^55 / 4 x 4.27x10^-12

3.83x10^26 = E / t

8.885 x10^43 / t = 3.83x10^26

t = 2.32x10^17 s / 3.15x10^7 s

= 7.36x10^9 years < 9x10^9

so wrong

ResultsPlus Examiner Comments

Both parts score full marks.

$4p \rightarrow He$

$(4 \times 1.0078) - 4.0026 = \frac{143}{5000}$ u

$1u \rightarrow 1.66 \times 10^{-27}$ kg

$\frac{143}{5000} \rightarrow$ kg

$kg = 4.74 \times 10^{-29}$

$E = mc^2$

$E = 4.74 \times 10^{-29} \times (3 \times 10^8)^2 = 4.27 \times 10^{-12}$ J

$2H_2 \rightarrow He$

$H_2 + H_2 \rightarrow HE$

Power = L = $\frac{\text{Energy}}{\text{Time}}$ $3.83 \times 10^{26} = \frac{1.242 \times 10^{46}}{t}$

10% of H_2 in sun = $\frac{10}{100} \times 1.39 \times 10^{30} = 1.39 \times 10^{29}$ kg time $= 3.24 \times 10^{19}$ s

yr $= 1029 \times 10^{9}$ years

$4(1.0078) \times 1.66 \times 10^{-27} \rightarrow 4.0026 \times 1.66 \times 10^{-27}$

$1.39 \times 10^{29} \rightarrow$ He kg $= 1.38 \times 10^{29}$

$E = mc^2 = 1.38 \times 10^{29} \times (3 \times 10^{8})^2 = 1.242 \times 10^{46}$ J

$\frac{3.83 \times 10^{26}}{} = \frac{1.242 \times 10^{46}}{t}$

Rate = $\frac{\text{mass of He}}{\text{Time}}$

time $= 3.24 \times 10^{19}$ s

$= 1029 \times 10^{9}$ years //

ResultsPlus
Examiner Comments

Part (a)(i) gains full marks, but (a)(ii) gains just 2 marks. In (a)(ii) there is an error of physics seen in a number of responses in which the mass of hydrogen fused (or the mass of helium formed as a result of fusion) is used in the Einstein equation [$\Delta E = c^2 \Delta m$].

Question 19 (b)

There was quite a lot of variation in the quality of responses, with some candidates merely repeating information given in the stem of the question. A significant number of responses focused on the forces that are balanced within a star, rather than explaining the transitions involved in the evolution of the star. Candidates tended to forget to locate fusion processes within the core of main sequence stars. It was often somewhat challenging to follow the evolution process being described, or explained, within the candidates' responses.

Some responses included a discussion of particle kinetic energy and overcoming repulsive electrostatic forces, which was an answer to a different question.

IC1 and IC2 were seen quite often, although it was relatively common for reference to fusion taking place in the core of the star to be omitted. IC3 was rarely credited, as the link between a decreasing rate of fusion and contraction was often not made. IC4 required a definite reference to helium fusion starting once an increase in the temperature (in the core) had occurred. IC5 should have been straightforward, but collapses and expansions were often muddled in many responses. IC6 was one of the most consistently credited statements.

Overall it is clear than many candidates were not able to express clearly the progression through the stars stages, with significant confusion about how a star goes from the end of fusion to an expansion into a red giant.

- Main Sequence Stars fuse hydrogen into helium in their cores.
- When hydrogen runs out, fusion stops and the core collapses due to gravitational forces. Temperature and pressure in the core increases, helium fusion begins and the Star expands to form a red giant. This change takes place first in high mass Stars. Once helium runs out, the outer atmosphere drifts away, a white dwarf is formed, white dwarfs are the remnants of red giants. No fusion takes place in white dwarves. ~~Surface area of white~~
- Main Sequence Stars are stable ~~when~~ because the outward radiation pressure is equal to the gravitational forces ~~collapse~~

ResultsPlus
Examiner Comments

This response is clearly expressed and the ideas, although minimalist in places, are logically sequenced. All the IC points apart from IC6 are seen, and so this response scores 5 marks.

Question 20 (a)

Almost half of the responses seen scored both marks. The usual reasons for not scoring both marks were either by referring to 'equilibrium' rather than 'equilibrium position', or trying to condense the key points into a single sentence and hence losing clarity.

There is a resultant force ~~always~~ proportional to the displacement from the equilibrium position

The resultant force always acts towards the equilibrium position.

ResultsPlus
Examiner Comments

This response states the two conditions clearly and accurately, and scores both marks.

- an osscilatory motion where the displacent is directly proportional to ~~the~~ acceleration
- And the ~~acce~~ acceleration acts towards the equillibrium position.

ResultsPlus
Examiner Comments

This response scores just 1 mark, for stating that the acceleration is directed towards the equilibrium position.

The statement about displacement is confusing. We need to see that the displacement is from the equilibrium position. In this response the statement starts with displacement, which may be the reason why "from the equilibrium position" has been forgotten.

ResultsPlus
Examiner Tip

Learn standard definitions for situations like this.

Question 20 (b)(i)

Many candidates could not relate the design of the damper system to resonance.

It was common to see responses that approached the question from the point of view that resonance was to be avoided, hence statements that natural frequency should not be equal to the driving frequency were common. Only a minority of candidates realised that a maximum transfer of energy to the damping system was desired, and most candidates focused on stating that energy transfer needed to be minimised.

the driving frequency of the wind matches with the natural frequency of the building, resonance occurs.
~~Allow the building to not be~~
preventing the builing from collaping.

ResultsPlus
Examiner Comments

In common with many responses seen, there is a recognition that resonance has to occur, although the detail relating to energy being dissipated or removed (ie an amplification of the term damping) is missing.

frequency
Because the driven ~~force~~ will be equal to the natural frequency, resonance will occur, and maximum energy will be transferred to the surroundings.

ResultsPlus
Examiner Comments

This is an example of a response gaining full marks. This was rare to see.

Question 20 (b)(ii)

Almost half of the responses scored full marks in this question.

In responses that did not score full marks, it was often due to rearrangement of the equation or other calculation mistakes. The square root in the equation for the period was often the culprit. Forgetting to give the units of their calculated value was another way not to gain full credit.

In the weakest responses MP1 was the only point credited, as attempts to solve the remainder of the problem used the Hooke's equation, *F* = *kx*.

$F = ma \quad F = -kx \quad m = \rho \times V$

$ka = m \qquad = 1130 \times 5.2^2 \times 0.9$

$= 274996.8$ kg

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

$\frac{1}{0.17} = 2\pi\sqrt{\frac{27.5\times10^3}{k}}$

$\frac{m}{k}$

$k = \left(\frac{1}{0.17}\times\frac{1}{2\pi}\right)^2$

$k = \frac{m}{\left(\frac{1}{0.17\times2\pi}\right)^2}$

Stiffness of spring system = 31375

ResultsPlus Examiner Comments

This is a correct solution, but MP5 is not given as the units are missing.

ResultsPlus Examiner Tip

Always give the units for the final answer in a calculation.

$\rho = m/V$

~~$\rho = mV$~~

$m = \rho \times V$

$= 11300 \times (5.20 \times 5.20 \times 0.9)$

$= 2.75 \times 10^5$ kg

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

$\left(\frac{T}{2\pi}\right)^2 = \frac{m}{k}$

$k = \frac{m \times 4\pi^2}{T^2}$

~~$\frac{1}{T} = f \Rightarrow f = 1/0.17 \Rightarrow$~~

$\left(T = \frac{1}{f} = \frac{1}{0.17} \Rightarrow 5.88\text{ s}\right)$

(4)

$\Rightarrow k = \frac{m \times 4\pi^2}{T^2}$

$k = \frac{2.75 \times 10^5 \times 4\pi^2}{5.88^2}$

$= 3.14 \times 10^5$ N m^{-1}

Stiffness of spring system = 3.14×10^5 N m^{-1}

ResultsPlus Examiner Comments

This is a correct solution scoring full marks.

Question 20 (b)(iii)

Generally, responses to this item were poor. Most responses referred to the springs exerting equal forces on the box which would cancel out. Of the responses that scored marks, MP1 and MP3 were most often seen.

The lead box has a lot of mass, so it has much inertia, so it will remain at rest, unless it is acted upon by a large force. The springs may apply a force on the box, however as $F=ma$ this force may not cause much acceleration due to the large mass

ResultsPlus
Examiner Comments

This response illustrates the most common way to gain the marks. There is reference to the box having a large inertia and the need for a large force to move it, as a result of its large inertia. This response gains full marks.

Question 20 (c)

Most candidates misunderstood this question. This may be because they did not connect the situation to the diagram given in the stem of the question. In many responses the focus was on lubrication, with many candidates thinking the oil was there to reduce friction.

because the rollers will receive a resistance force, then the work is done against this force, so the energy of the oscillation will be transferred to surroundings, so the amplitude will decrease

ResultsPlus
Examiner Comments

This response says just enough for both marks. There isn't a direct reference to oil, but the stem of the question makes it clear that the situation is about oil being forced through holes and so this is fine.

Because now, there is no friction produced through the rollers on the steel plate. So efficiency of the damper increases as there is less resultant force (friction) is acting on it. So it helps to reduce the amplitude of the oscillating building.

ResultsPlus
Examiner Comments

This response is typical of many responses seen. The oil is considered as a lubricating agent (which in many situations would be the case). However, how this would reduce the amplitude of the building is not explained. The response therefore did not score any marks.

Paper Summary

Based on their performance on this paper, candidates should:

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