Pearson Edexcel

Examiners' Report
June 2022

IAL Physics WPH15 01

ResultsPlus

Introduction

The assessment structure of WPH15 mirrors that of other units in the specification. It consists of 10 multiple choice questions, a number of short answer questions and some longer, less structured questions. As an A2 assessment unit, synoptic elements are incorporated into this paper. There is overlap with circular motion and exponential variation in Unit 4, but also overlap with some of the AS content from Units 1 and 2.

This paper gave 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.

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 accurate solutions that were clearly set out. Occasionally in calculation questions the final mark was lost due to a missing unit. Candidates understood the convention that in the 'show that' questions it was necessary to give the final answer to at least one more significant figure than the value quoted in the question. Not all candidates recognised the importance of showing all stages in their working in this type of question.

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 Q14 and Q17(c), where candidates had knowledge of the topic but could not express it accurately and succinctly. Candidates could improve by ensuring they describe all aspects in sufficient detail and always use appropriate specialist terminology when giving descriptive answers.

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

There was some evidence of candidates learning previous schemes in the expectation of earning marks but less so than in previous exam series. Candidates should be encouraged to work with mark schemes in preparation for their exam. However, it is important that they understand that mark schemes are written for examiners, and so sometimes refer to what examiners expect to see rather than giving a complete answer.

Question 11

Almost all candidates were able to select the appropriate equation and to use the data given in the question to reach the correct value for the distance of the galaxy from Earth. A few candidates forgot that they had been told that the luminosity of the standard candle was 14800 times the luminosity of the Sun and just used the value for L_{Sun} meaning that only MP2 could be awarded. Other errors included mistakes in rearranging the equation or omitting the unit for the distance.

11 A standard candle in the galaxy M81 has a luminosity 14800 times the luminosity of the Sun. The intensity of radiation received from the standard candle, measured at the top of the Earth's atmosphere, is $3.64 \times 10^{-17}\ \text{W m}^{-2}$.

Calculate the distance of the M81 galaxy from Earth.

$L_{Sun} = 3.83 \times 10^{26}\ \text{W}$

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

$$d^2 = \frac{L}{I \times 4\pi} = \frac{3.83 \times 10^{26}}{3.64 \times 10^{-17} \times 4\pi}$$

$$d = \sqrt{8.37 \times 10^{41}}$$

Distance of M81 from Earth = 9.15×10^{20} m

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Examiner Comments

This response scored 1 mark.

The first sentence of the question has been ignored. Instead of using 14800 times the luminosity of the Sun as the luminosity of the standard candle, this candidate has just used the value given for the luminosity of the Sun. They have used the equation for intensity correctly, but their final answer is incorrect. Therefore, only the second marking point was awarded.

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Examiner Tip

Check that your solution has used all the data given in the question.

11 A standard candle in the galaxy M81 has a luminosity 14 800 times the luminosity of the Sun. The intensity of radiation received from the standard candle, measured at the top of the Earth's atmosphere, is $3.64 \times 10^{-17}\,\mathrm{W\,m^{-2}}$.

Calculate the distance of the M81 galaxy from Earth.

$L_{Sun} = 3.83 \times 10^{26}\,\mathrm{W}$

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

$$d = \sqrt{\frac{14800 \times 3.83 \times 10^{26}}{4\pi \times 3.64 \times 10^{-17}}}$$

$$\therefore d = 1.11 \times 10^{23}\ \mathrm{m}$$

Distance of M81 from Earth = 1.1×10^{23} m

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Examiner Comments

This candidate has rearranged the equation before substituting the numbers. The working is easy to follow, the final answer is correct and includes the unit.

All 3 marks were awarded.

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Examiner Tip

Make it easy for the examiner to follow your working. Write down all the steps in your working.

Question 12 (a)

Q12(a)(i)

Prior knowledge of the unit megaparsec (Mpc) is not required.

It is necessary to realise that to achieve a unit for the Hubble constant of s^{-1}, either velocity in ms^{-1} and distance in m, or velocity in kms^{-1} and distance in km are needed. Therefore, all that is required is to rearrange the equation $v = H_0 d$ to make H_0 the subject and to substitute given values with an appropriately positioned conversion factor.

The command is to 'show that'. It is essential in this type of question to show all steps in the working, and to give the final numerical answer to at least one more significant figure than is given in the question as the 'show that' value. In this question the 'show that' value is $2.3 \times 10^{-18}\ s^{-1}$, hence the final answer should be given to at least 3 significant figures. It is not essential to include the unit since it has been given.

Q12(a)(ii)

Most candidates realised that they could find the age of the universe by finding the reciprocal of the Hubble constant given in part (i), and that this gave them a value in seconds. A second stage in their calculation using the information about the number of seconds in a year given in the question gave them the age in years as required.

Some candidates attempted the calculation in one step and made various mistakes. Others failed to notice that they had been told the number of seconds in a year and wasted time doing the calculation from first principles.

12 Astronomers often use the unit megaparsec (Mpc) for astronomical distances. In a textbook a value for the Hubble constant is given as $72\,\text{km}\,\text{s}^{-1}\,\text{Mpc}^{-1}$.

(a) (i) Show that $72\,\text{km}\,\text{s}^{-1}\,\text{Mpc}^{-1}$ is equivalent to a Hubble constant of about $2.3 \times 10^{-18}\,\text{s}^{-1}$.

$1\,\text{Mpc} = 3.09 \times 10^{22}\,\text{m}$

$$\frac{72\ \text{km}}{\text{Mpc s}}$$

(2)

$$= \frac{72}{3.09 \times 10^{22}} \times 1000$$

$$= 2.33 \times 10^{-18}\ \text{s}^{-1}$$

$$\simeq 2.3 \times 10^{-18}\ \text{s}^{-1} \text{ (shown)}$$

(ii) Determine a value for the age of the universe in years.

$1\ \text{year} = 3.16 \times 10^{7}\,\text{s}$

(2)

$$\text{Age} = \frac{1}{2.3 \times 10^{-18}}$$

$$= 4.35 \times 10^{17}\ \text{s}$$

$$= 1.38 \times 10^{10}\ \text{years}$$

Age of universe = 1.38×10^{16} years

ResultsPlus Examiner Comments

Q12(a)(i)

This candidate realised that to obtain a value for H_0 it is necessary to divide velocity by distance. They have included a factor of x 1000 in the numerator to show the conversion from kms^{-1} to ms^{-1}. The answer is given to 3 significant figures, which is one more than the 'show that' value.

This scores 2 marks.

Q12(a)(ii)

We can see that the age has been calculated by taking the reciprocal of the 'show that' value of the Hubble constant, to give the correct value in seconds. The conversion to years has been done correctly, so both marks are awarded.

This scores 2 marks.

ResultsPlus Examiner Tip

Set your work out clearly so that the examiner can easily understand your method.

(ii) Determine a value for the age of the universe in years.

1 year = 3.16×10^7 s

(2)

$\frac{1}{2.3\times10^{-18}}$

$= 4.29\times10^{17}$ s

$\frac{4.29\times10^{17}}{3.16\times10^{7}}$

$= 1.36$ years

Age of universe = 1.36 years

ResultsPlus Examiner Comments

Q12(a)(ii)

The method used to reach a value for the age of the universe is correct, but the candidate has forgotten to include the power of 10 in their answer.

The first marking point is awarded. They have not quoted the equation, but because substitution of the Hubble constant is shown it is clear that they have used the equation.

ResultsPlus Examiner Tip

Always check that you have transferred the whole value from your calculator display to your answer paper, including the power of 10.

Question 12 (b)

The context of the question led most candidates to consider the age of the universe and how it is calculated from the reciprocal of the Hubble constant. Many of these responses mentioned that the value of H_0 would be smaller and so the age of the universe would be greater. Whilst this is a correct statement, it has not fully addressed the information given that the galaxies are **twice** as far away as had been previously thought and as a consequence only scored one mark.

Those candidates that attempted to explain how the calculated age of the universe would change without reference to the Hubble constant rarely made sufficient progress to score any marks.

(b) In the 1950s, astronomers realised that they had made an error in their determination of distances to galaxies. Galaxies are twice as far away as astronomers had previously thought.

Explain how this changed the age of the universe as calculated by astronomers.

(2)

$H_0 = \frac{v}{d}$. Since the distance to galaxies is doubled the Hubble constant must be halved. According to age of the universe $= t = \frac{1}{H_0}$ since the Hubble constant is halved the age of the universe must be twice the age calculated by astronomers

(Total for Question 12 = 6 marks)

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Examiner Comments

An example of a response that scores both marks.

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Examiner Tip

If you are asked to 'explain', then your answer may include relevant formulae, but you must also describe how the formulae are used.

(b) In the 1950s, astronomers realised that they had made an error in their determination of distances to galaxies. Galaxies are twice as far away as astronomers had previously thought.

Explain how this changed the age of the universe as calculated by astronomers.

(2)

- $v = H_0 d$, As distance is more so Hubble constant will be less
- As Hubble constant is less ~~th~~ so the age of the universe will be more, as $T = \frac{1}{H_0}$.

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Examiner Comments

This candidate has the right idea but has not used the information that the galaxies are **twice** as far away. This scores 1 mark.

ResultsPlus
Examiner Tip

When you read through your answer, check that you have used all the information given.

Question 13 (a)

This is a straightforward question and a type that has been asked many times before on this paper. It is expected that candidates will know that a beta minus particle is an electron and how to represent this particle in a nuclear equation. Then to balance the proton numbers and nucleon numbers on either side of the equation.

Question 13 (b)

The question asked for similarities between the particles, but it was surprising how many responses gave differences. For example, it was not unusual to see a statement that the particles have equal but opposite charge. The most common creditworthy similarities were that the particles have the same mass and the same magnitude charge. Other factors were mentioned that, whilst not untrue, did not contribute to a question that is looking for physical similarities, these were treated as neutral statements. Examples of these include the same proton number or nucleon number.

Question 13 (c)

This is the first of several questions on the paper where the command is to **deduce** something.

Almost all candidates were able to find a value for the decay constant.

Most then proceeded to use the exponential equation to find the time for the activity to fall to background level. Most candidates successfully answered this, although some muddled the initial and final activities or thought that they had to subtract the background count rate from the initial activity of the fertilizer. Another approach was to use the exponential equation to find the activity after 9×10^9 years.

Approaches that involved working out the number of half-lives to reach background level and hence the time taken could score all the marks.

To satisfy the command to deduce, it was necessary to give the correct value for either time or activity **and** its unit **and** to comment that the claim in the question was incorrect.

Some candidates had not read the claim with sufficient care and thought that despite their having the correct value for time or activity, the claim was correct.

(c) A fertiliser contains potassium chloride. The activity of a sample of the fertiliser due to radioactive potassium was 48.6 Bq.

It is claimed that the time t taken for the activity of the sample to fall below the background count rate would be more than 9×10^9 years.

Deduce whether this claim is correct.

background count rate = 0.42 Bq
half-life of $^{40}K = 1.25 \times 10^9$ years

(3)

$\lambda = \frac{\ln 2}{t_{1/2}} = \frac{\ln 2}{1.25 \times 10^9} = 5.55 \times 10^{-10}\ \cancel{s^{-1}}\ yr^{-1}$

$A = A_0 e^{-\lambda t} = 48.6 \times e^{-5.55 \times 10^{-10} \times 9 \times 10^9} = 0.33\ Bq$

This activity is smaller than the backround count rate so the claim is correct

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Examiner Comments

A correct numerical solution but one that only scores the first two marks.

This candidate has understood that in a question of this type they must back up their calculation with a comment but has not fully understood the claim given in the question. They have actually shown that the activity has fallen to below background count rate in less than 9×10^9 years, so their conclusion is incorrect.

ResultsPlus
Examiner Tip

Take special care to notice when you are asked to deduce something and complete your answer with an appropriate comment.

(c) A fertiliser contains potassium chloride. The activity of a sample of the fertiliser due to radioactive potassium was 48.6 Bq.

It is claimed that the time t taken for the activity of the sample to fall below the background count rate would be more than 9×10^9 years.

Deduce whether this claim is correct.

background count rate = 0.42 Bq
half-life of $^{40}K = 1.25 \times 10^9$ years

(3)

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

$\lambda = \frac{\ln 2}{1.25 \times 10^9}$

$\lambda = 5.55 \times 10^{-10}$ years^{-1}

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

$\ln\left(\frac{A}{A_0}\right) = -\lambda t$

$t = \frac{\ln\left(\frac{A}{A_0}\right)}{-\lambda}$

$= 1.56 \times 10^9$ years

∴ Claim is wrong

ResultsPlus
Examiner Comments

The first marking point is awarded because we can see that the candidate has found a value for the decay constant by substituting the half-life into the correct equation. They have left the time in years which is acceptable, there is no need to change the time into seconds.

The algebra shown suggests that they know how they should attempt to find the time for the activity of the sample to fall to background level, but the final numerical answer is not correct and no substitutions are shown. No further marks are scored.

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Examiner Tip

Always show the values you substitute when solving equations.

Question 14

The introductory sentence should have led candidates to think about resonance and how it applies to the two situations described.

It was clear that many candidates thought that both situations were examples of resonance. The first situation, the finger striking the glass is not an example of resonance, the glass will oscillate at its natural frequency, but it is not being forced. The finger sliding around the top of the glass does provide a forcing frequency, thus forcing the glass to oscillate and resonance will occur.

Many candidates had the idea that the glass would only emit sound for a short time because the oscillations are damped, or that energy will be transferred from the oscillating system, but they failed to add that this will result in the amplitude decreasing and so did not meet IC2.

Most candidates could not describe the condition for resonance in this specific situation and instead used vague or imprecise language. It was rare to see that it was the natural frequency **of the glass** that was matched by the driving frequency of the finger.

All candidates should at least have been able to give a correct description of what resonance means and meet the requirements for IC5 and IC6.

Explain these observations.

Resonance occurs when the driving frequency caused by the finger is equal to the natural frequency of the glass so there is maximum energy transfer and hence amplitude of oscillations increase to maximum. When glass is gently struck, there is sound emitted as energy transfer ~~from~~ to glass causes the glass to oscillate, where the magnitude of ~~the~~ amplitude shows how loud the ~~vol~~ sound will be. Glass only emits sound for short time as there is damping caused by air and water in glass, absorbing energy so amplitude falls. When wet finger is slid around top of glass, driving frequency and energy (work done by finger) transferred to glass is continuously at the ~~max~~ natural frequency of glass so resonance occurs in which loud sound is produced due to maximum energy transfer to glass and hence loud continuous sound is produced.

ResultsPlus Examiner Comments

An example of a response that scored all 6 marks.

All the indicative content points have been made and the points are presented logically, with technical language used correctly.

ResultsPlus Examiner Tip

Take time to think and plan your response carefully before starting to write.

Question 15 (a)

Q15(a)(i)

The majority of candidates could complete this calculation successfully. Of those who failed to score all 3 marks, the most common error was in calculating the mass difference. Some candidates confused which masses to add and which to subtract, with some not including all three masses.

Q15(a)(ii)

Almost all candidates realised that they needed to use the equation for kinetic energy and could apply the 98% correctly to the energy they had calculated in Q15(a)(i).

Some failed to identify that the mass of the alpha particle was given in the table at the top of the page and attempted to use other masses, for example 4 × proton mass. These responses could not score both marks.

(a) (i) Show that the energy released in the decay is about 9×10^{-13} J.

(3)

$$\Delta m = (3.48572 \times 10^{-25}) - (3.41918 \times 10^{-25}) - (6.64431 \times 10^{-27})$$

$$\Delta m = 9.63 \times 10^{-30}$$

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

$$\Delta E = (9.63 \times 10^{-30}) \times (3 \times 10^8)^2$$

$$\Delta E = 8.7 \times 10^{-13} \text{ J}$$

(ii) 98% of the energy from the decay is released as kinetic energy of the alpha particle.

Calculate the velocity of the alpha particle immediately after the decay.

(2)

$$\frac{98}{100} \times 8.7 \times 10^{-13} = 8.494 \times 10^{-13} \text{ J}$$

$$K.E = \tfrac{1}{2} m v^2 \qquad v = \sqrt{\frac{8.494 \times 10^{-13} \times 2}{6.64431 \times 10^{-27}}} \qquad v = 1.6 \times 10^7 \text{ m/s}$$

Velocity of alpha particle = 1.6×10^7 m/s

ResultsPlus
Examiner Comments

An example of a response that scores full marks 3 + 2.

The working is clearly set out and all stages have been shown.

In (i) the answer has been given to more significant figures than the 'show that' value.

In (ii) the unit has been given as well as the correct numerical answer.

ResultsPlus
Examiner Tip

Ensure that the examiner can understand how you have solved the question.

Question 15 (b)

This question elicited a range of incorrect responses, including comments about energy being transferred to the surroundings, and references to binding energy.

It was necessary to consider the decay process and appreciate that momentum must be conserved. In order to do this, the two products of the decay, the alpha particle and the lead nucleus, must move in opposite directions. In other words, the lead nucleus recoils.

(b) Explain why not all of the energy from the decay is released as kinetic energy of the alpha particle.

(2)

This is because Lead-206 is also decayed into. Momentum conservation needs to take place and as the mass of Lead is much higher, it gains kinetic energy but only a very small amount.

ResultsPlus Examiner Comments

The response has identified that momentum must be conserved so the 1st mark is awarded.

Question 16 (a)(i)

The first stages of this solution were well understood, but not always as clearly presented as we would like, but usually included sufficient algebra for the first two marks to be awarded.

The majority of candidates did not, however, appreciate that T^2 is only proportional to r^3 if the remaining terms in the equation are constant, and it is essential to say this as part of the answer.

16 The planets orbit the Sun in approximately circular orbits. The orbital time T of a planet is related to the average distance r of the planet from the Sun.

(a) (i) Show that T is related to r by the expression:

$$T^2 \propto r^3$$

↗ g ↗ CF

(3)

$$\frac{GM_1M_2}{r^2} = \frac{mv^2}{r} / mw^2r$$

$$\frac{G\cancel{M_1}M_2}{r^2} = \cancel{m}\left(\frac{2\pi}{T}\right)^2 r$$

$$\frac{G}{r^2} = \left(\frac{2\pi}{T}\right)^2 r$$

$$\frac{G}{r^3} = \left(\frac{2\pi}{T}\right)^2$$

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

Hence, $T^2 \propto r^3$ so

T^3 is related to the average distance of r^3

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Examiner Comments

This response starts with an ambiguous first line. The candidate probably means that the right hand side could be written either in terms of v or in terms of ω, but that is not what they have written.

It does help us to understand their next line which shows the expression for gravitational force equated to the expression for centripetal force, but with ω^2 replaced by $(2\pi/T)^2$. At this stage marking point 1 is awarded.

After this all the masses have disappeared and so the final expression is incorrect and no further marks are awarded.

ResultsPlus
Examiner Tip

Be very careful and set your work out logically.

Question 16 (a)(ii)

This was a challenging question that required candidates to use their knowledge of the principles of circular motion and of gravitational fields and to apply that knowledge in an unfamiliar context. There were a few excellent responses showing impressive problem-solving skills and using a variety of approaches.

Many candidates did not attempt the question. Those candidates that did attempt it, were usually able to score the first 2 marks. Having just shown that T^2 is proportional to r^3, they were able to use this, together with the given data about the Earth and Jupiter, to find a value for T_{Jupiter} the time for Jupiter to orbit the Sun. Other candidates attempted a much longer process, doing the calculation from first principles.

$$\frac{T_{Earth}}{R_{Earth}} = \frac{T_{Jupiter}}{R_{Jupiter}}$$

$$\frac{12^2}{(1.5\times10^{11})^3} = \frac{T^2}{(7.8\times10^{11})^3}$$

T = 142 ~~moths~~ months

∴ This statements is incorrect

ResultsPlus
Examiner Comments

An example of a response where the candidate has sensibly made use of the relationship they have just derived, to find the period of Jupiter as 142 months.

Marking points 1 and 2 are awarded.

ResultsPlus
Examiner Tip

Remember that the different parts of a question are related and you may find clues as to how to proceed in a previous part of the same question.

Question 16 (b)

Using the expression for gravitational potential remains difficult for many candidates. Responses showed that the use of this expression is not well understood. Some candidates used the expression for either or both of the given distances but failed to understand that they had found an energy per unit mass.

Some candidates had memorised an equation, which enabled them to do the calculation in one step which is acceptable provided the equation has been correctly memorised and accurately used.

(b) The distance of Jupiter from the Sun varies from 7.4×10^{11} m to 8.2×10^{11} m.

Calculate the change in gravitational potential energy of Jupiter as it moves from its closest distance to its furthest distance from the Sun.

mass of Sun = 2.0×10^{30} kg
mass of Jupiter = 1.9×10^{27} kg

(3)

$$\Delta V_{grav} = \frac{6.67 \times 10^{-11} \times 2 \times 10^{30}}{7.4 \times 10^{11}} - \frac{6.67 \times 10^{-11} \times 2 \times 10^{30}}{8.2 \times 10^{11}}$$

$$= 1.76 \times 10^{7}$$

$$\Delta E_{grav} = 1.9 \times 10^{27} \times 1.76 \times 10^{7}$$

$$= \underline{3.34 \times 10^{34}}$$

Change in gravitational potential energy = 3.34×10^{34}

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Examiner Comments

A correct solution but only scoring 2 of the 3 marks because the unit of energy is missing.

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Examiner Tip

Always remember to include the unit in your final answer.

Question 17 (a)

Candidates have been asked many times in the past to make a statement about the conditions for simple harmonic motion. It is a standard definition and one that candidates should be ready to state without difficulty.

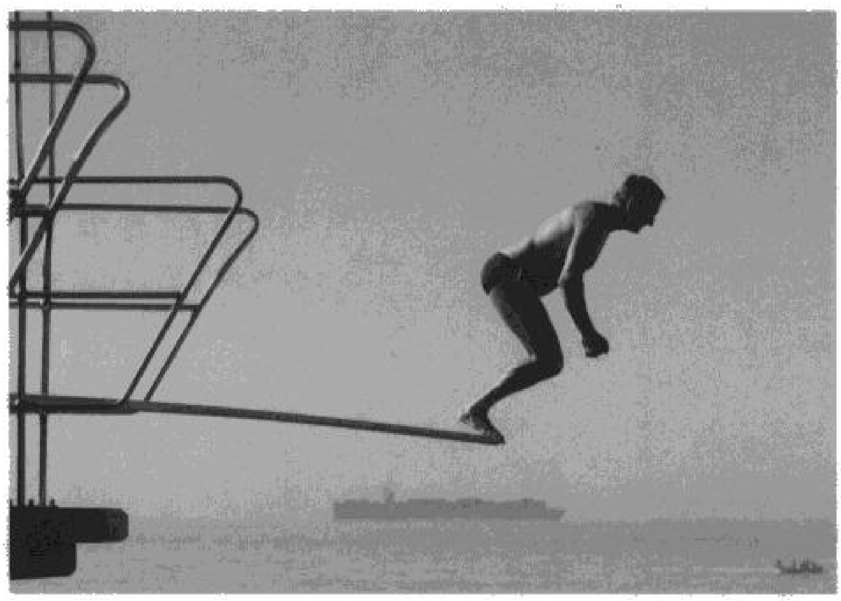
The question can be answered either in terms of force or acceleration, but not a mixture of both.

For the first mark it is essential to specify displacement and not distance and also to state where the displacement is measured from. ‘Equilibrium' is a technical word in physics and means a state not a position.

It is necessary to include something about the direction of the force or the acceleration for the second mark. This mark was more commonly awarded than the first.

17 A man is about to dive into the sea from a high diving board. The board is horizontal before he walks to the end of the board.

When the man stands on the end of the board, it bends as shown.



(Source: © Fuse/Getty Images)

(a) By pushing on the board, the man displaces the end of the board a small distance downwards. The man and the board then oscillate with approximate simple harmonic motion.

State the conditions for simple harmonic motion.

(2)

Acceleration of the object must be directly proportional to its displacement.
And the acceleration must always act towards the equilibrium point.

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Examiner Comments

Only the second mark can be awarded.

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Examiner Tip

Learn this definition carefully.

Question 17 (b)

Q17(b)(i)

It was unusual to see responses that did not score both marks here.

Q17(b)(ii)

For many candidates this was a straightforward calculation. Having been told that the diving board obeys Hooke's law and calculated a value of k, the stiffness of the board, candidates realised that they could use the equation for a simple harmonic oscillator, an expression more usually associated with a mass and spring to obtain a value of the periodic time. Then all that was required was to use $f = 1/T$.

It is incorrect use of physics to attempt to use the expression for a simple pendulum, or to assume that the acceleration of the man on the board is the acceleration due to the Earth's gravitational field. Both of these could lead to a numerically correct answer, but the only mark that might be awarded is marking point 2.

Question 17 (c)

This is a challenging question, testing candidates' depth of understanding of the forces or acceleration in simple harmonic motion, but in an unfamiliar context. Referencing back to part (a), where candidates had to state the conditions for simple harmonic motion, might have helped them to frame an answer.

Sometimes responses that might have scored marks, did not do so because symbols were used that had not been defined, or imprecise language was used. It was unclear for example, whether force was the resultant force or the normal contact force. Candidates often muddled amplitude and displacement.

Responses were sometimes in terms of resonance, perhaps prompted by an earlier question.

(c) If the $\boxed{\text{amplitude of oscillation}}$ is large enough, the man will lose contact with the board at a point above the equilibrium position.

Explain why.

(3)

Above the equilibrium position, the resultant force = weight - normal contact force. If the amplitude is very large, the acceleration and hence the resultant force will also be very large. As the resultant force increases, weight staying the same, the normal ~~const~~ contact force must decrease. When the normal force decrease to zero, the man will lose contact with the board.

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Examiner Comments

This is one of the better attempts at this question.

This response is talking about the forces involved so we are using the 1st alternative mark scheme.

The first line scores the first mark. There is the idea that the contact force decreases but they have not said that it decreases as displacement increases.

The final sentence scores the 3rd mark, giving a total of 2 marks.

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Examiner Tip

Try to use precise physics terminology.

Question 18 (a)(i)

In general, this question was well answered. Candidates could use trigonometry with sine or tan or use the small angle approximation. If used correctly all give the same answer.

Some candidates started correctly but arrived at an incorrect answer because their calculator was set to degrees not radians. Others used half or twice the parallax angle. All these could be awarded the first mark although the final answer was not correct.

Question 18 (a)(ii)

Although candidates often said that the value of the parallax angle for distant stars is very small, it was much less common to see answers where the relationship between distance and the size of the angle was clearly stated, which is the requirement for marking point 1.

Some candidates did include that the method can only be used for stars that are close to the Earth and so scored the alternative for the first mark.

Answers tended to focus on the uncertainty in the value of the parallax angle rather than on the fact that for most stars the parallax angle is too small to measure.

(ii) Explain why parallax measurements can only be used to determine the distances to a relatively small number of stars.

(2)

Since parallax angle can only be used if the star is close enough to the Earth. If the star is very far away, the angle 'θ' is very small which gives a large % uncertainty

ResultsPlus Examiner Comments

A response that scores the first mark only.

ResultsPlus Examiner Tip

Try to think about the reality of huge astronomical distances.

Question 18 (b)

Q18(b)(i)

This question enabled the majority of candidates to score all three marking points.

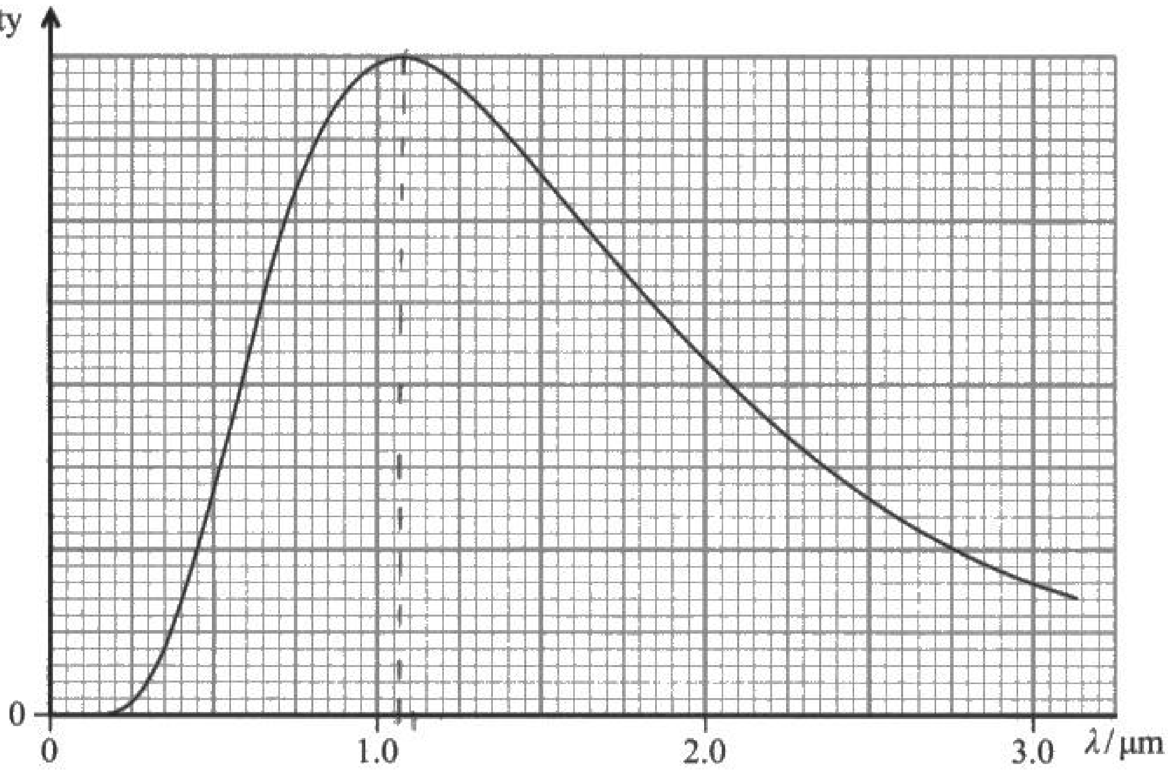
Q18(b)(ii)

The use of the Stefan-Boltzmann law remains a problem for some candidates because they have not memorised the equation for the surface area of a sphere, $A = 4\pi r^2$.

It should have been possible to calculate the luminosity of Wolf using the information given in the question to score the first two marks. It was necessary to see the correct unit for this luminosity as well as the correct value.

In order to deduce whether the claim is correct or not, further calculation is required, a comparison made, and a conclusion drawn.

(b) The graph shows how the intensity of radiation from the star Wolf 359 varies with wavelength.



(i) Show that the surface temperature of Wolf 359 is about 2700 K.

(3)

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

$T = \frac{2.898 \times 10^{-3}}{1.075 \mu} = \frac{2.898 \times 10^{-3}}{1.075 \times 10^{-6}} = \underline{\underline{2696\ K}}$

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Examiner Comments

Q18(b)(i)

This scored all three marks. We can see from their graph that they are attempting to measure the wavelength of the peak intensity. Their value of λ has been read correctly from the x-scale, and they have used Wien's law to arrive at a temperature within the accepted range.

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Examiner Tip

Using the graph to make it clear where your value comes from is good practice, especially in a 'show that' question.

Question 19 (a)

This calculation can be done in two stages, using the ideal gas equation to determine either T or kT, and then using the equation given at the back of the question paper, mean kinetic energy = $3kT/2$.

Alternatively, the two equations may be combined algebraically, and the calculation done in one stage.

Most candidates could do this successfully using either route, giving the correct value for the energy with the correct unit.

Some candidates proceeded to multiply this value of the mean kinetic energy by the number of mercury atoms, thus obtaining a value for the total kinetic energy of the gas. This is not what the question has asked for, meaning that only the first two marks could be awarded.

19 The spectrum of light emitted by the star Chi Lupi provides evidence of mercury atoms in the outer layers of the star. The light emitted from the star is compared with light emitted from a mercury lamp on Earth.

(a) The lamp contains 1.65×10^{19} mercury atoms in a volume of $1.50 \times 10^{-5}\,m^3$. The pressure of the mercury vapour is 4.25×10^4 Pa.

Calculate the mean kinetic energy of the mercury atoms.

(3)

$PV = NkT$

$kT = \frac{(4.25\times10^{4})(1.50\times10^{-5})}{(1.65\times10^{19})}$

$kT = 3.86\times10^{-20}$

$E_k = \frac{3}{2}kT$

$= \frac{3}{2}(3.86\times10^{-20})$

$= 5.80\times10^{-20}$ m/s

Mean kinetic energy of mercury atoms = 5.80×10^{-20}

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Examiner Comments

In this response the ideal gas equation has been used to find a value of *kT*. At this stage a unit is not required.

The value of the mean kinetic energy is correct, but the unit has been written as m/s instead of J.

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Examiner Tip

Always check that you have included the correct unit.

Question 19 (b)

Another example of a question where the command is to ‘deduce’. In this case, to deduce whether the student’s conclusions were correct. It is necessary to note that there are two parts to the student’s conclusion, and to score all the marks it is essential to address both parts.

Most candidates began by attempting to calculate the velocity of the star by using the given expression for the redshift of electromagnetic radiation. However it was clear from the responses we saw that many candidates do not understand that the value of the wavelength used in the denominator of that equation must be the wavelength of the spectral line produced on Earth and not the wavelength of the line in the spectrum received from the star.

It is insufficient to simply say that the calculated velocity is equal to the student’s velocity and so the conclusion is incorrect. There must be more of a comparison. As a minimum, a statement that the velocity is greater than 1400 ms^{-1} and so the student's conclusion is incorrect.

To address the other part of the student’s conclusion about the direction of the star’s movement, it is necessary to make a comment comparing the measured wavelength from the star and the wavelength from the lamp. It is not sufficient just to say that the light is blue shifted.

(b) One line in the spectrum of light from Chi Lupi has a wavelength of 576.933 nm. The equivalent line in a mercury spectrum produced on Earth is 576.959 nm.

A student concluded from this data that Chi Lupi is moving towards the Earth, and that the relative velocity of Chi Lupi is about $1400\,\mathrm{m\,s^{-1}}$.

Deduce whether the student's conclusions are correct.

(4)

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

$$\Rightarrow \frac{576.959 - 576.933}{576.933} = \frac{v}{3 \times 10^8}$$

$$\Rightarrow v = 13519\ \mathrm{ms^{-1}}$$

$\therefore\ v = 14000\ \mathrm{ms^{-1}}$ which is greater than $1400\ \mathrm{ms^{-1}}$ and so claim is false

ResultsPlus Examiner Comments

The value of the wavelength used in the denominator is not the wavelength of the line in the spectrum produced on Earth, but the correct value of velocity has been found with a unit. Only one of the first two marks is awarded.

They have made a comparison between their calculated velocity and the value in the student's conclusion, and correctly commented that the student's conclusion is false. The 4th mark is awarded.

A total of 2 marks scored.

ResultsPlus Examiner Tip

Read the question very carefully to make sure that you haven't missed anything.

Question 19 (c)

Responses showed that most candidates had a limited understanding of what the Hertzsprung-Russell diagram with its logarithmic scales shows. The characteristics of Chi Lupi as described in the question, mean that the star is still a main sequence star, but with a greater luminosity than the Sun and a higher temperature. The log scale on the diagram means that Chi Lupi must be above the Sun and to its left.

'At the top of the main sequence' was credited as a minimum acceptable answer.

Answers that were seen many times but not credited included red giant, red supergiant, blue supergiant, top of the HR diagram.

Question 20 (a)

Q20(a)(i)

This question is an example of a synoptic question, requiring a very straightforward application of equations of motion met in WPH11. It was surprising that many candidates did not realise how to tackle it.

Q20(a)(ii)

We saw many very good responses showing understanding of how to use the specific heat capacity and specific latent heat equations as well as knowledge of how to calculate the volume of a sphere and its mass.

Some candidates got as far as calculating the total energy but then didn't take the extra step to work out the rate of energy transfer.

(ii) The lead sphere has a radius of 1.2 mm. As it falls it cools from 615 K to 370 K. The molten lead solidifies at 601 K.

Calculate the mean rate at which energy is transferred from the lead sphere to the surroundings. You should assume that the specific heat capacities of liquid lead and solid lead are the same.

density of lead = $1.13 \times 10^4\,kg\,m^{-3}$
specific latent heat of lead = $2.47 \times 10^4\,J\,kg^{-1}$
specific heat capacity of lead = $130\,J\,kg^{-1}\,K^{-1}$

$d = \frac{m}{v}$

(6)

$E = mc\Delta\theta + mL$

$E = 1.13\times10^4 \times \frac{4}{3}\times\pi\times(1.2\times10^{-3})^3\times 130\times(615-370) + 1.13\times10^4\times\frac{4}{3}\times\pi\times(1.2\times10^{-3})^3\times 2.47\times10^4$

$E = 4.63\,J$

$P = \frac{4.63}{2.91} = 1.59\,W$

Mean rate of energy transfer from lead = 1.59 W

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Examiner Comments

Q20(a)(ii)

This candidate has done the calculation of the energy transfer all in one go. Not a recommended approach, but all their substitutions can be seen so even if they had made an arithmetic error the process marks could have been awarded.

The final stage to find power is also shown and the correct value reached, and the unit is also stated.

All 6 marks were awarded.

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Examiner Tip

If you do a calculation in one go, be sure to include all your substitutions.

Question 20 (b)(i)

Those candidates that attempted an algebra-based explanation were far more likely to score marks on this question than those who attempted at a purely descriptive explanation.

Responses that were not creditworthy but often seen were mass is negligible, or mass is constant.

The teacher turns the tube upside down, and the lead shot falls through a distance d.

The teacher repeats this N times and measures the final temperature of the lead shot. The change in temperature $\Delta\theta$ of the lead shot is calculated.

The teacher uses the values of d, N and $\Delta\theta$ to determine a value for the specific heat capacity c of the lead.

(i) Explain why the mass of lead shot in the tube should not affect the value of $\Delta\theta$.

(2)

Because the mass of a sphere is so small that it can be negligible

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Examiner Comments

An example of a response that is not creditworthy.

The previous question involved calculating the mass of the lead shot. Whilst the mass of one lead sphere is a fraction of a gramme, the diagram shows many of them, so a comment that the mass is negligible cannot be true.

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Examiner Tip

If you do not know the answer to a question, think about the context before making a guess.

Question 20 (b)(ii)

Of the candidates who attempted this question, many were able to score the first mark because they could give a sensible comment equivalent to not all the energy is used to increase the temperature of the lead shot.

It was uncommon to be able to award the second mark.

Paper Summary

Based on their performance on this paper, candidates should:

- learn the equations for the surface area and volume of a sphere.
- where questions ask for a description or explanation, be particularly careful to use appropriate scientific terminology.
- in ‘show that’ questions, include all substitutions and all stages in the working.
- ensure they have a thorough knowledge of the physics for this unit.
- read the question carefully and answer what is asked.