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June 2023

GCE Physics 9PH0 02

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Introduction

The assessment structure of Advanced Paper 2 is the same as that of Paper 1, consisting of ten multiple choice questions and a number of short answer questions followed by longer, structured questions based on contexts of varying familiarity.

This paper allowed candidates of all abilities to demonstrate their knowledge and understanding of Physics by applying them to a range of contexts with differing levels of familiarity.

Candidates at the lower end of the range could complete calculations involving simple substitution and limited rearrangement, including structured series of calculations, but could not always tackle calculations involving several steps or other complications, such as using temperature changes in specific heat capacity calculations and temperatures in kelvin with gas equations. They also knew some significant points in explanations linked to standard situations, such as atomic spectra and diffraction gratings, but frequently missed important details and did not always set out their ideas in a logical sequence, sometimes just quoting as many key points as they could remember without particular reference to the context.

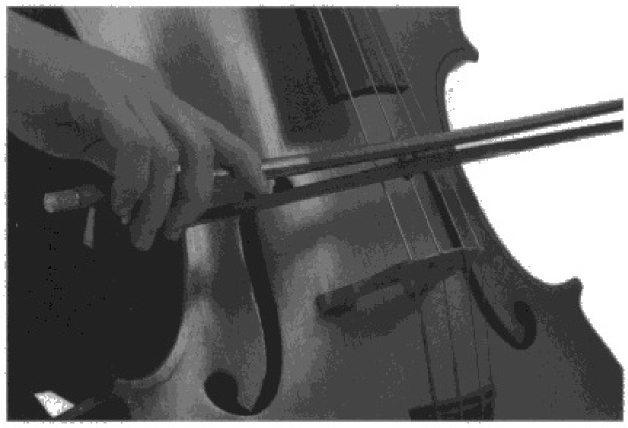
Steady improvement was demonstrated in all of these areas through the range of increasing ability and at the higher end, all calculations were completed faultlessly and most points were included in ordered explanations of the situations in the questions.

Question 11

While candidates were helped by knowing the effect of a thicker string on frequency from experience, the requirement in this question was to use the information provided regarding the length and tension to arrive at the answer by a process of logical deduction, which a majority of candidates achieved, being awarded at least three marks. Few candidates were unable to state that the mass per unit length was greater, although some omitted 'per unit length', and most candidates who mentioned that knew that this resulted in a lower wave speed, although not all quoted the relationship $v = \sqrt{(T/m)}$ to justify this. Those candidates obtaining three marks arrived at the correct conclusion but did not include a reference to the constant wavelength.

Some candidates confused T for tension with T for period and said v is constant, so if m increases, period increases and frequency decreases.

11 The photograph shows a stringed instrument called a cello being played with a bow.



(Source: © Vadim Ponomarenko/Alamy Stock Photo)

A standing wave forms on a cello string when the bow moves across the string.

Deduce whether a thicker string will produce a note of higher or lower frequency compared with a thinner string.

Assume each string is the same length and at the same tension.

$v = \sqrt{\frac{T}{\mu}}$ where μ = mass per unit length.

As same length, a thicker string has larger mass, so μ is bigger.

$v \propto \frac{1}{\sqrt{\mu}}$ → so larger mass means smaller wave speed.

$v = f\lambda$

~~fx~~ $v \propto f$.

↳ ∴ thicker string has a lower frequency compared to thinner string.

(Total for Question 11 = 4 marks)

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Examiner Comments

3 marks. This follows the required steps, only failing to state that the wavelength is the same.

11 The photograph shows a stringed instrument called a cello being played with a bow.

(Source: © Vadim Ponomarenko/Alamy Stock Photo)

A standing wave forms on a cello string when the bow moves across the string.

Deduce whether a thicker string will produce a note of higher or lower frequency compared with a thinner string.

Assume each string is the same length and at the same tension.

- ~~$v=\sqrt{\frac{T}{\mu}}$~~ Thinner string has smaller mass per unit length
- $v=\sqrt{\frac{T}{\mu}}$, the wavespeed of the wave would be bigger due to a smaller μ
- Same length of the string means same ~~wavel~~ wavelength ~~o~~ for waves
- $f=\frac{v}{\lambda}$, an increased v and a fixed λ results in higher frequency f ~~of~~ for thinner string

ResultsPlus
Examiner Comments

4 marks. This includes all of the relevant physics but approaches it in terms of the thinner string. As there are only two possibilities, this answers the question.

Question 12

The great majority of candidates applied the equation $\Delta E = mc\Delta\theta$ and demonstrated an understanding of the application of conservation of energy to the situation, equating energy lost by the block to energy gained by the container of water, although many candidates did not include the glass. Nearly half of the candidates were able to complete this to calculate the correct value for specific heat capacity. Only about a quarter of these, however, correctly explained that the block was copper by referring to energy transferred to the surroundings. Most candidates assumed incorrectly that, as the value was closest to that for tin, tin was the metal used. A substantial minority of candidates were unable to complete the calculation correctly because they either used the stated temperatures without calculating a temperature change, or they used the temperature change of 4 K for the block as well as the water and the glass container. A few candidates went further astray by converting Celsius temperatures to kelvin.

12 A student placed a metal block of mass 220 g in boiling water at 100 °C for several minutes.

The student then transferred the metal block into 300 g of water at 19 °C inside a glass container of mass 50 g. The final temperature of the water was 23 °C.

The table shows specific heat capacity values for copper and tin.

Metal	copper	tin
Specific heat capacity / $J\,kg^{-1}\,K^{-1}$	390	230

Deduce whether the metal block was made from copper or tin.

specific heat capacity of water = $4200\,J\,kg^{-1}\,K^{-1}$
specific heat capacity of glass = $840\,J\,kg^{-1}\,K^{-1}$

$Q = 0.3 \times 4200 \times 4 = 5040\ J$

$Q = 0.05 \times 840 \times 4 = 168\ J$

$5040 + 168 = 5208\ J$

$5208 = 0.22 \times c \times (100 - 23)$

$c = 307.4$

$307.4 - 230 = 77.4$ ~~307.4~~ $390 - 307.4 = 82.6$

Closer to tin

So block is tin

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Examiner Comments

2 marks. In this response the specific heat capacity has been calculated correctly, but the conclusion is incorrect as it has been based on which of the values is closer without considering whether practical factors, such as heat transferred to the surroundings, would be expected to make the final result smaller or greater than expected.

12 A student placed a metal block of mass 220 g in boiling water at 100 °C for several minutes. → I assume the block reaches 100°C before being removed

The student then transferred the metal block into 300 g of water at 19 °C inside a glass container of mass 50 g. The final temperature of the water was 23 °C.

The table shows specific heat capacity values for copper and tin.

Metal	copper	tin
Specific heat capacity / J kg^{-1} K^{-1}	390	230

Deduce whether the metal block was made from copper or tin.

specific heat capacity of water = 4200 J kg^{-1} K^{-1}
specific heat capacity of glass = 840 J kg^{-1} K^{-1}

$\Delta E = mc\Delta\theta$

Energy released by copper block: $m = 0.220$ kg

$\Delta\theta = -77°C$, $c = 390$

$\Delta E = 0.220 \times 390 \times -77$

$= -6606.6\ J = 6.6\ kJ$

E. released by tin block: $\Delta E = 0.220 \times 230 \times -77 = -3896.2\ J$

$= -3.9\ kJ$

$\Delta E = 0.300 \times 4200 \times 4° + 0.050 \times 840 \times 4 = 5208\ J$ = Energy transferred to water & glass

$5208\ J > 3896\ J$, ∴ the block can't be made out of tin, the energy ~~released by~~ change in the tin block isn't enough

$5208\ J < 6600\ J$, ∴ the block was made of copper. The difference of 1400 J was dissipated to the surroundings.

(Total for Question 12 = 5 marks)

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Examiner Comments

5 marks. This response shows a different approach by considering the maximum energy transferable by each block. The required comparisons are made, leading to a correct conclusion.

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Examiner Tip

Where you are asked to make a judgement or to come to a conclusion by command words such as ‘determine whether’ or ‘deduce whether’, you must make a clear statement, including any values being compared. If it is a numerical comparison, you must show all steps in your calculation.

Question 13 (a)

About half of the candidates gained at least two marks, being far more likely to be awarded them for describing the conditions required for fusion in a star than in a fusion reactor. The mark for very high temperature applied in either case and was frequently not awarded because of a lack of detail with candidates stating 'high temperature' rather than 'very high temperature'.

Quite a few candidates either misinterpreted the question or simply applied a learned response from a previous mark scheme because they explained the conditions in a star rather than describing them. For example, they wrote that a very high temperature was required so that nuclei had sufficient kinetic energy to overcome the Coulomb repulsion, but the mark only required 'very high temperature'. While there is nothing wrong with the extra information, it suggests that some candidates should remind themselves of the requirements indicated by different command words, such as 'describe' versus 'explain' so that they are sure to include the required detail.

13 A fusion research centre was opened in Rotherham in 2021. The centre has a device which tests materials in the extreme conditions found inside a fusion reactor.

(a) Describe the extreme conditions inside a fusion reactor.

(3)

Boron rods are used to control the reactor. Extreme temperatures are used to ensure a collision is made, along with slow speeds.

ResultsPlus
Examiner Comments

0 marks. This is clearly referring to fission rather than fusion, but it still makes a comment about temperature. Extreme temperature could refer to extremely high or extremely low, so it is not credited.

13 A fusion research centre was opened in Rotherham in 2021. The centre has a device which tests materials in the extreme conditions found inside a fusion reactor.

(a) Describe the extreme conditions inside a fusion reactor.

(3)

Veryh high temperature to overcome the electrostatic forces of repulsion between positivley charged nuclei. Very high density so particles are close together ~~ta~~ so ~~a~~ collide more so there is sufficent collision rate

ResultsPlus
Examiner Comments

2 marks. The question asks for a description, with three marks indicating three conditions, but this response gives explanations for two conditions and is remarkably similar to the answer required for a question seen in previous series about fusion in stars.

ResultsPlus
Examiner Tip

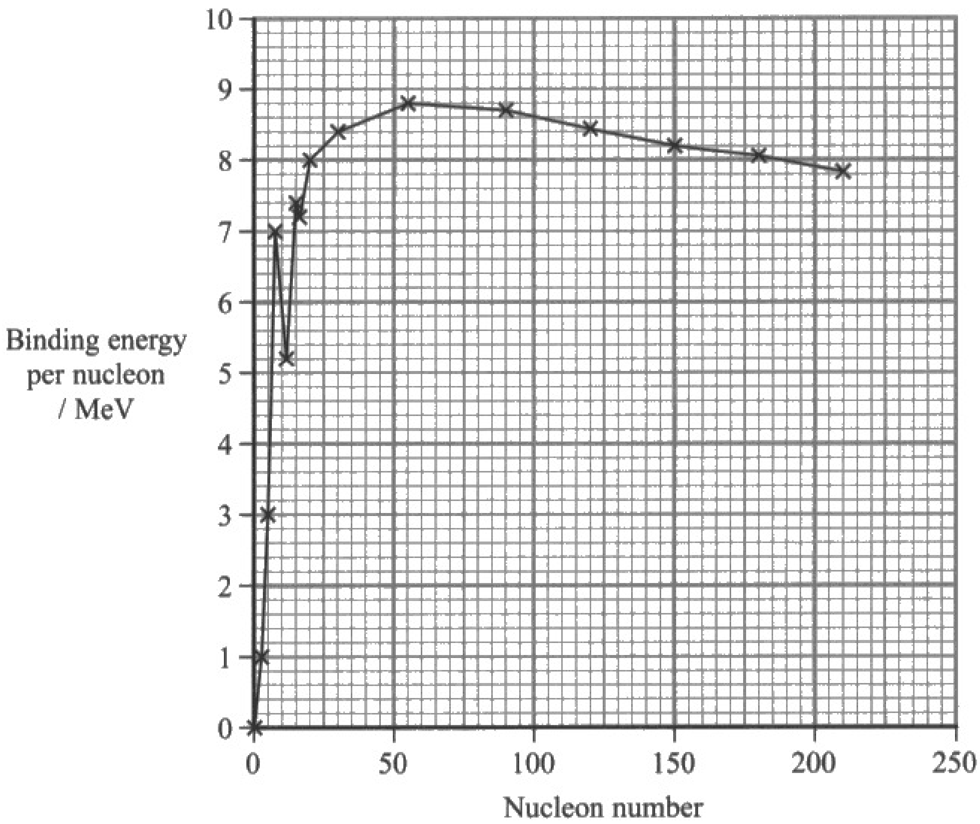
Questions may be similar to something you have seen in a previous paper, but they are unlikely to be identical. Beware of giving a prepared answer to a different question.

Question 13 (b)

While the majority of candidates gained some credit for this question, very few obtained all three marks.

Candidates were able to demonstrate some knowledge and understanding of binding energy related to fusion, but responses often lacked sufficient detail, with imprecise descriptions of the process of fusion, for example, not including reference to smaller nuclei fusing to make larger nuclei. References to the graph rarely included numerical data demonstrating the increase in binding energy per nucleon, sometimes just stating, incorrectly, that fusion only occurs for nuclei with a nucleon number below 55. There was also evidence of confusion with the terms nuclei, nucleon and nuclide.

(b) The graph shows how the binding energy per nucleon varies with nucleon number for a range of nuclides.



Explain why the fusion of nuclei can produce large amounts of energy. Your answer should refer to information from the graph.

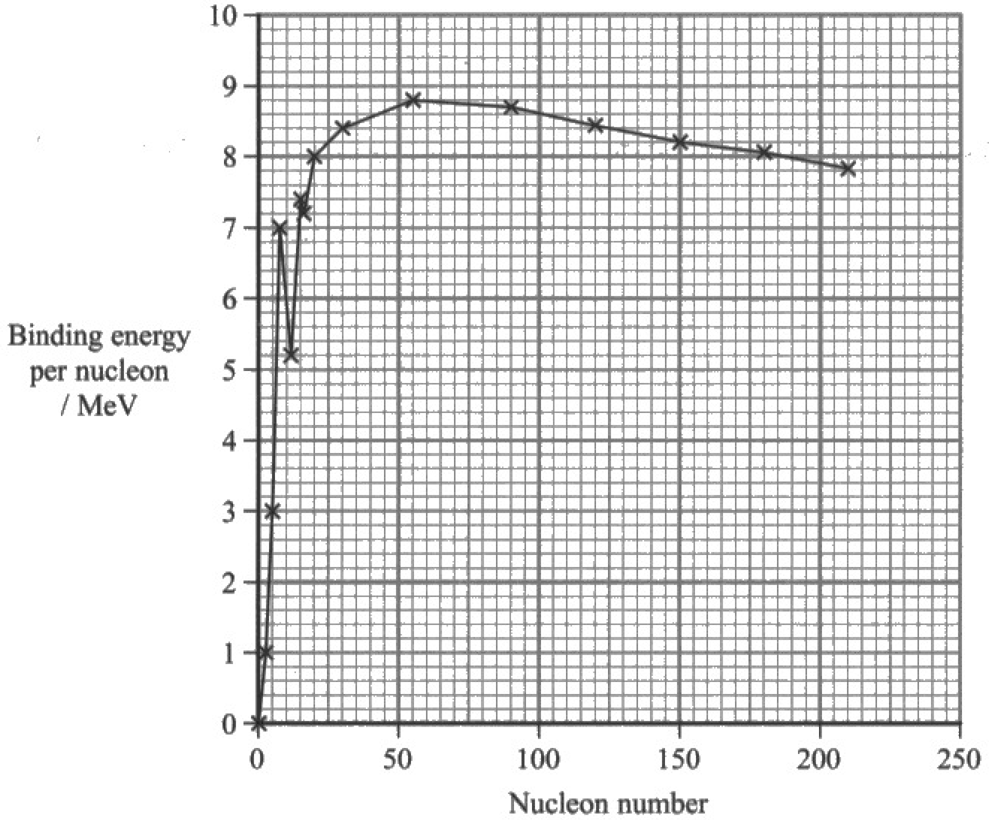
(3)

During fusion nuclei with lower nucleon numbers fuse together forming a larger heavier nuclei with a larger nucleon number. This larger nucleon number means that the binding energy per nucleon is greater, which the graph supports and if the binding energy per nucleon increases then lots energy has been released.

ResultsPlus
Examiner Comments

2 marks. The first two points are as required, but it just says it is supported by the graph without extracting any particular information from the graph to demonstrate this support.

(b) The graph shows how the binding energy per nucleon varies with nucleon number for a range of nuclides.



Explain why the fusion of nuclei can produce large amounts of energy. Your answer should refer to information from the graph.

(3)

- the large nucleon has a greater binding energy per nucleon than the two smaller nuclei
- for example:

Binding energy of the two smaller nuclei

12 × ~~5.2×10^10~~ 5.2 MeV = 62.4 MeV

15 × 7.4 = 111 MeV

Binding energy of larger nucleon

(Total for Question 13 = 6 marks)

∴ energy produced = 111 − 62.4 = 48.6 MeV

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Examiner Comments

2 marks. This response is a good example of using data from the graph effectively, but it misses the first mark because there is no clear statement about the mentioned smaller nuclei fusing to make the larger one.

Question 14 (a)

This was intentionally a high demand question and only about a fifth of candidates were able to gain credit for their responses, usually for stating that energy must be supplied in order to convert a liquid to a gas. Candidates rarely referred to the internal energy of the liquid at any stage, and even more rarely stated was how it affected the temperature of the cylinder itself. A very frequent response was to attempt to explain this using gas laws. One version of this involved saying that the pressure will decrease as gas leaves the cylinder and pressure is proportional to temperature, so temperature decreases. Even if candidates quoted $pV = NkT$, they failed to appreciate that their explanation would require constant N and so was clearly not appropriate. Whatever candidates wrote about the gas was ultimately irrelevant, however, because they needed to discuss the internal energy of the liquid and/or the cylinder, which they did not tend to do.

14 The fuel used in a camping stove is butane, which is stored in a canister as shown.

butane canister

camping stove

Some of the butane in the canister is in a liquid state, and some is a gas.

(a) When the stove uses the butane gas, some of the liquid butane evaporates.

Explain why the temperature of the canister decreases when the stove is used.

(3)

As the liquid evaporates, (thermal) energy activity as an input is required to change ~~sta~~ the state of matter, where the internal, more specifically potential, energy of the system is increased (related by the specific latent heat of vaporisation). Due to the conservation of energy, the average random kinetic energy of the canister/particles must decrease (transferred to the liquid).

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Examiner Comments

2 marks. This includes most of the relevant points but lacks a final statement relating to the temperature or the internal energy of the canister.

14 The fuel used in a camping stove is butane, which is stored in a canister as shown.

Some of the butane in the canister is in a liquid state, and some is a gas.

(a) When the stove uses the butane gas, some of the liquid butane evaporates.

Explain why the temperature of the canister decreases when the stove is used.

(3)

When butane evaporates, energy is used to break the bonds between molecules, decreasing the average kinetic energy of molecules in liquid butane, therefore, decreasing the temperature of liquid butane.

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Examiner Comments

3 marks. A succinct answer including all of the required points.

Question 14 (b)(i)-(ii)

Candidates performed well on this multistage calculation across the ability range, with about half being awarded full marks. The common errors in Q14(b)(i) were failing to convert temperature to kelvin or using an incorrect formula to calculate volume. A few candidates also chose the wrong constant *k*, using the Coulomb law constant rather than the Boltzmann constant.

In Q14(b)(ii) the most common error was failing to complete the final square root and leaving the mean square value, although we might have expected candidates to realise that 130 000 m s^{-1} is too fast. Some candidates calculated the correct value but omitted the unit and so were not awarded the final mark.

(b) The pressure inside the canister is 220 kPa and the temperature of the gas is 21 °C.

(i) The canister is in the shape of a cylinder of length 0.23 m and radius 0.11 m.

Calculate the number of molecules of butane gas in the canister.

Assume the volume of liquid butane inside the canister is negligible.

(4)

Volume : $\pi\ 0.11^2 = 0.03801\ m^2$

$0.03801 \times 0.23 = 8.74 \times 10^{-3}\ m^3$

$pV = NkT$

$\frac{220 \times 10^3 \times 8.74 \times 10^{-3}}{k \times 294} = N$ $\qquad N = 4.39 \times 10^{26}$

Number of molecules of butane gas = 4.39×10^{26}

(ii) Calculate the r.m.s. speed of the molecules of butane gas.

mass of butane molecule = 9.6×10^{-26} kg

(2)

$pV = \frac{1}{3} Nm\ c^2$

$\sqrt{\frac{220 \times 10^3 \times 8.74 \times 10^{-3}}{\frac{1}{3} \times 4.39 \times 10^{26} \times 9.6 \times 10^{-26}}} = c$

r.m.s. speed = 11.72 ms^{-1}

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Examiner Comments

Q14(b)(i) 2 marks. The volume calculation is correct and temperature has been converted to kelvin. The third mark for use of $pV = NkT$ is not awarded because the Boltzmann constant has been left as k and not substituted using the value given in the paper.

Q14(b)(ii) 2 marks. Using the value for N in Q14(b)(i) this has been processed correctly, so full marks are awarded with the error carried forward.

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Examiner Tip

Where you do not get the correct final answer, you may still be awarded marks for your working. For this mark to be awarded, there must be full substitution of values, including all constants, into a correct equation and there must be one unknown only.

(b) The pressure inside the canister is 220 kPa and the temperature of the gas is 21 °C.

(i) The canister is in the shape of a cylinder of length 0.23 m and radius 0.11 m.

Calculate the number of molecules of butane gas in the canister.

Assume the volume of liquid butane inside the canister is negligible.

(4)

$pV = NkT$

$220k \times ((0.11)^2\pi \times 0.23) = N(1.38 \times 10^{-23})(\overset{294}{\cancel{+273}})$

$1923.47 = N(\overset{4.0572 \times 10^{-21}}{\cancel{3.47 \times 10^{-21}}})$

$N = \cancel{5.53 \times 10^{23}}\ 4.74 \times 10^{23}$ (3sf)

Number of molecules of butane gas = 4.74×10^{23}

(ii) Calculate the r.m.s. speed of the molecules of butane gas.

mass of butane molecule = 9.6×10^{-26} kg

(2)

$pV = \frac{1}{3}Nm\langle c^2\rangle$

$1923.47 = 1/3\,(4.74 \times 10^{23})(9.6 \times 10^{-26})\langle c^2\rangle$

$\langle c^2\rangle = 126811.149\ldots$ $c_{rms} = \frac{356}{\sqrt{2}} = 251.8$

$\langle c\rangle = 356$

r.m.s. speed = $252\ ms^{-1}$

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Examiner Comments

Q14(b)(i) 4 marks. Fully correct answer.

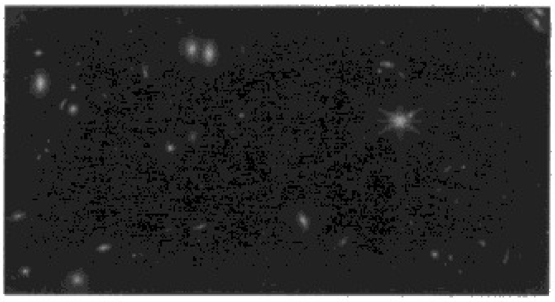
Q14(b)(ii) 1 mark. The correct answer has been calculated, but the response indicates uncertainty about what is meant by r.m.s. in this context and it is treated as it would be for an alternating current, so the final answer mark is not awarded. Note also the unnecessary number of significant figures in the working. These are not penalised, but writing too many digits can make it easier to transpose them or miss some out while copying them from the calculator display.

Question 15 (a)(i)

While very few candidates did not understand this relatively familiar derivation, slightly over a third were not awarded the mark because they showed too few stages, subsuming speed = distance / time into another step and not stating it separately.

24 mins

15 The photograph below was taken by the James Webb Space Telescope (JWST) and shows a group of galaxies that formed shortly after the big bang, about 13×10^9 years ago.



(Source: © NASA, ESA, CSA, STScI)

(a) (i) Derive the equation $T = 1/H_0$ where T is the age of the universe.

(1)

$v = H_0 d$

$\frac{d}{t} = H_0 d \qquad \frac{1}{t} = H_0$

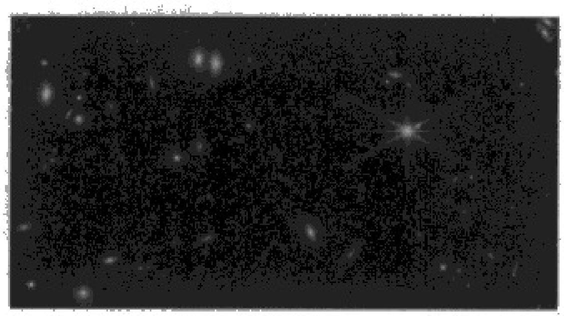
ResultsPlus Examiner Comments

0 marks. v = d/t has been substituted without being shown separately.

ResultsPlus Examiner Tip

When deriving an equation, be sure to show each of the equations being used separately before substituting it.

15 The photograph below was taken by the James Webb Space Telescope (JWST) and shows a group of galaxies that formed shortly after the big bang, about 13×10^9 years ago.



(Source: © NASA, ESA, CSA, STScI)

(a) (i) Derive the equation $T = 1/H_0$ where T is the age of the universe.

(1)

$V = H_0 d$ $\quad \cancel{d = \frac{v}{t}} \quad v = \frac{d}{t}$

$\frac{d}{t} = H_0 d \quad \frac{1}{t} = H_0 \quad T = \frac{1}{H_0}$

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Examiner Comments

1 mark. This shows all the required steps.

Question 15 (a)(ii)

Only about a third of candidates stated an appropriate assumption. Some were too general, such as 'nothing can exceed the speed of light', or already in the question, such as 'the Universe started expanding 13 × 10^9 years ago', or already part of the derivation, such as 'distance is proportional to time'. Others were ambiguous, such as 'speed is constant', without indicating which speed, or incorrect, such as 'the speed of the Universe is constant' rather than 'the speed of Maisie is constant'.

(ii) State one assumption made in your derivation.

(1)

assume speed of expansion of the universe is and has always been constant

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Examiner Comments

0 marks. This refers to the constant speed of the Universe, but the Hubble equation assumes different speeds for galaxies at different distances, so it is not awarded the constant speed mark which should refer to the galaxy Maisie.

(ii) State one assumption made in your derivation.

(1)

That the distance of ~~of~~ galaxy isn't changing as well as the speed at which it's travelling

ResultsPlus
Examiner Comments

0 marks. This is a contradictory answer because if the galaxy has a speed that isn't changing it must have a distance that is changing.

(ii) State one assumption made in your derivation.

(1)

The galaxies have had negligible or no acceleration, staying at a constant velocity since the beginning of the universe

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Examiner Comments

1 mark. This links constant velocity to particular galaxies.

Question 15 (a)(iii)

A good majority of candidates were able to calculate the Hubble constant in units of s^{-1} and almost half of them were able to complete this fully, including a full conclusion with comparisons of all the relevant values. Those candidates who could not gain on the third point generally had difficulty in converting to the unit quoted for the range in the question.

(iii) The parsec (pc) is a unit used for astronomical distances. 1 pc is 3.1×10^{16} m.

The accepted range for the Hubble constant H_0 is (60–80) km s^{-1} Mpc^{-1}.

Deduce whether the observation by the JWST leads to a value of H_0 within the accepted range.

1 year = 3.16×10^7 s

(3)

$\cancel{H_0 = \frac{1}{13 \times 10^9 \times 365 \times 24 \times 60 \times 60}}$

$H_0 = \frac{1}{13 \times 10^9 \times 3.16 \times 10^7} = 2.434274586 \times 10^{-18}$

$H_0 = 60 \times 3.1 \times 10^{16} \times 10^6 = 1.86 \times 10^{24}$

$80 \times 3.1 \times 10^{16} \times 10^6 = 2.48 \times 10^{24}$

$\cancel{3.1 \times 10^{16} \times 2.434 \times 10^{-18}}$

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Examiner Comments

2 marks. This is an acceptable approach, that involves a bit more work. The answers are correct, but there is no conclusion.

(iii) The parsec (pc) is a unit used for astronomical distances. 1 pc is 3.1×10^{16} m.

The accepted range for the Hubble constant H_0 is (60–80) km s^{-1} Mpc^{-1}.

Deduce whether the observation by the JWST leads to a value of H_0 within the accepted range.

1 year = 3.16×10^7 s

(3)

$1\text{pc} = 3.1 \times 10^{16}$

$T = \frac{1}{H_0} = \frac{1}{\ }$

LOWER

$H_0 = $ ~~[illegible]~~ $= \frac{60 \times 10^3}{3.1 \times 10^{16} \times 10^6}$

$= 1.9 \times 10^{-18}$

$\frac{1}{H_0} = 5.2 \times 10^{17}$ s

$T = 1.6 \times 10^{10}$ years

UPPER

$H_0 = \frac{80 \times 10^3}{3.16 \times 10^{16} \times 10^6}$

$= 2.6 \times 10^{-18}$

$\frac{1}{H_0} = 3.9 \times 10^{17}$ s

$T = 1.2 \times 10^{10}$ years

$13 \times 10^9 \rightarrow 1.3 \times 10^{10}$

so yes within accepted range

$1.2 \times 10^{10} \rightarrow 1.6 \times 10^{10}$ years

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Examiner Comments

3 marks. This is another method, well set out, and includes a clear conclusion with the comparison of values supported by the conversion of the age of the Universe to the same power of ten as the calculated answers.

Question 15 (b)(i)

Most candidates attempted to apply the redshift equation, but a majority of those who did incorrectly used the wavelength of the detected radiation as the denominator when they should have used the wavelength of the emitted radiation as the denominator and the difference between the wavelengths as the numerator. The numerator was often incorrectly given as initial wavelength minus final wavelength rather than the converse.

Quite a few candidates who correctly substituted into the red shift equation made an algebraic error in their final rearrangement, subtracting λ from 14λ rather than adding it.

(b) The light from one of the galaxies, called Maisie, has a redshift z of 14.
The wavelength of light from Maisie detected at the telescope is 4.0×10^{-6} m and lies within the infrared section of the electromagnetic spectrum.

(i) Calculate the wavelength of light emitted by Maisie.

(3)

$$z = \frac{\Delta\lambda}{\lambda}$$

$$14 = \frac{(\lambda - 4.0 \times 10^{-6})}{4 \times 10^{-6}}$$

$$\lambda = 6 \times 10^{-5} \text{ m}$$

Wavelength emitted = 6×10^{-5} m.

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Examiner Comments

1 mark. This demonstrates two of the errors described.

(b) The light from one of the galaxies, called Maisie, has a redshift z of 14.
The wavelength of light from Maisie detected at the telescope is 4.0×10^{-6} m and lies within the infrared section of the electromagnetic spectrum.

R
m
I
V
u
x
Y

(i) Calculate the wavelength of light emitted by Maisie.

(3)

$z = 14 \qquad 14 = \frac{v}{c} \approx \frac{\Delta\lambda}{\lambda}$

$14 = \frac{4\times10^{-6} - \lambda}{\lambda} \qquad \lambda(14-1) = 4\times10^{-6}$

$\lambda = 3.08\times10^{-7}$

$14\lambda = 4\times10^{-6} - \lambda$

Wavelength emitted = 3.08×10^{-7}

ResultsPlus
Examiner Comments

2 marks. The wavelengths have been used correctly, but there is an algebraic error at the end with the subtraction of 1 when it should be addition.

(b) The light from one of the galaxies, called Maisie, has a redshift z of 14. The wavelength of light from Maisie detected at the telescope is 4.0×10^{-6} m and lies within the infrared section of the electromagnetic spectrum.

(i) Calculate the wavelength of light emitted by Maisie.

(3)

$$14 = \frac{4 \times 10^{-6} - \lambda}{\lambda}$$

$$14\lambda = 4 \times 10^{-6} - \lambda$$

$$15\lambda = 4 \times 10^{-6}$$

$$\lambda = 2.7 \times 10^{-7}$$

Wavelength emitted = 2.7×10^{-7}

ResultsPlus
Examiner Comments

2 marks. All of the working is correct, including the calculation of the final answer, but the unit has been omitted, so the final mark has not been awarded.

ResultsPlus
Examiner Tip

In questions with a specific answer line for a numerical value, you will not be awarded the final mark for a calculation if the unit is not included.

Question 15 (b)(ii)

A large majority of candidates were awarded at least one mark, most frequently the second mark for stating that Maisie is moving away from the Earth. Others were awarded the first mark for stating that the wavelength had increased, but many responses lacked sufficient detail, referring to the light being stretched, or just to the light being redshifted, which they knew from the question. Some candidates said that it moved to the red end of the spectrum, but, without reference to the starting point, this was insufficient.

(ii) Explain why the light emitted by Maisie arrives at the telescope as infrared.

(2)

The wavelength of light emitted is shifted towards the longer wavelengths which is towards red and infrared

ResultsPlus
Examiner Comments

1 mark. Answers that just referred to light being shifted towards the red end of the spectrum were not awarded marks, but this mentions longer wavelengths.

(ii) Explain why the light emitted by Maisie arrives at the telescope as infrared.

(2)

The doppler effect caused ~~the wavelength of~~ light from the galaxy which is accelerating away from us to be stretched. Therefore its wavelength increases causing it to be infrared.

ResultsPlus
Examiner Comments

2 marks. This response includes reference to 'stretched' but qualifies this by stating that wavelengths increase. The galaxy is described as moving away from us.

Question 15 (c)

Several approaches were seen. The most common was comparing photon energy in eV with the work function but many candidates compared the frequency of the radiation with the threshold frequency. While the majority of candidates were able to apply all of the relevant formulae for 3 marks, they did not appreciate what they had calculated and made the final comparison incorrectly, for example concluding that, since 0.31 eV is greater than 0.30 eV, the detector could not detect the light.

(c) One of the infrared detectors on the JWST is made from material with a work function of 0.30 eV.

Deduce whether this detector can detect the light from Maisie.

(4)

$hf = \phi + \frac{1}{2} m v_{max}^2$

$hf = 0.3 \times 1.6 \times 10^{-19}$

$f = \frac{0.3 \times 1.6 \times 10^{-19}}{6.63 \times 10^{-34}} = 7.2398 \times 10^{13}$ is required frequency to meet work function requirement.

$c = f\lambda$.

$\lambda = \frac{3 \times 10^8}{7.2398 \times 10^{13}} = 4.14 \times 10^{-6}$ m. , recieved λ is 4×10^{-6}.

as $4.14 > 4$, detector can not detect light.

ResultsPlus Examiner Comments

3 marks. In this response the threshold frequency is calculated and then used to find the corresponding wavelength. There is a comparison of wavelengths, but the conclusion is incorrect as there is a failure to recognise that a longer wavelength represents a lower photon energy.

(c) One of the infrared detectors on the JWST is made from material with a work function of 0.30 eV.

$v = f\lambda$.

Deduce whether this detector can detect the light from Maisie.

(4)

$E = hf \qquad hf = \phi + \frac{1}{2}mv^2_{max}$.

$f = \frac{v}{\lambda} = \frac{(3\times10^8)}{4\times10^{-6}} = 7.5\times10^{13}$ Hz.

$hf = \phi$.

$\phi = (6.63\times10^{-34})(7.5\times10^{13}) = 4.97\times10^{-20}$ J

$= 0.311$ eV

$\therefore$ can detect light from Maisie.

(Total for Question 15 = 14 marks)

ResultsPlus
Examiner Comments

3 marks. There is a correct calculation of photon energy in eV and a correct conclusion, but the energy values have not been directly compared, so the final mark is not awarded.

Question 16 (a)

As a concept many will have encountered first at Key Stage 3, candidates clearly knew what the elastic limit is, but only about a quarter answered the actual question precisely enough to be awarded a mark. The key missing detail in most cases was a reference to the removal of the load. A lot of candidates made a statement in terms of not being plastic without saying what plastic means.

16 The suspension system in a car includes a spring attached to each wheel as shown.

(Source: © Macrovector/Shutterstock)

The car, of mass 1100 kg, is stationary. Each spring is compressed by 152 mm due to a quarter of the weight of the car. Each spring is well within both the limit of proportionality and the elastic limit.

(a) State what is meant by within the elastic limit.

(1)

The point at which a spring stops deforming elastically and starts plastic deformation

ResultsPlus
Examiner Comments

0 marks. This is not incorrect, but the use of 'elastically' doesn't answer a question about 'elastic' and just referring to 'plastic' without saying what is meant by that term is still not answering the question.

16 The suspension system in a car includes a spring attached to each wheel as shown.

(Source: © Macrovector/Shutterstock)

The car, of mass 1100 kg, is stationary. Each spring is compressed by 152 mm due to a quarter of the weight of the car. Each spring is well within both the limit of proportionality and the elastic limit.

(a) State what is meant by within the elastic limit.

(1)

Within the limit of which when the force is released the spring will return to its original shape

ResultsPlus
Examiner Comments

1 mark. An example of a correct answer.

Question 16 (b)(i)-(ii)

As with Q14(b), performance was encouraging in this multi-step calculation, with nearly three quarters of the candidates straightforwardly gaining at least 5 out of 6 marks. The main error made by those scoring 5 rather than 6 marks was failing to divide the oscillating mass of the car equally between the four springs in Q16(b)(ii), even when they did so in Q16(b)(i), admittedly with the help of a 'show that' value to work towards.

A few candidates were able to arrive at a correct result for frequency using the pendulum formula, but, as this was incorrect physics, they were not awarded marks.

(b) (i) Show that the stiffness of each spring is about 18 000 N m^{-1}.

(3)

$m = 1100\,kg$

$\Delta x = 152 \times 10^{-3}\,m$

$F = k\Delta x$

$k = \dfrac{(\frac{1}{4} \times 1100) \times 9.81}{152 \times 10^{-3}} = 17748\,N\,m^{-1}$

$\approx 18\,000\,N\,m^{-1}$

(ii) A force is applied to the car which results in a further small compression of each spring. The force is then removed, and the body of the car oscillates with simple harmonic motion.

Determine the frequency of the oscillations.

(3)

$\frac{1}{f} = 2\pi\sqrt{\frac{m}{k}}$

$\frac{1}{f} = 2\pi\sqrt{\frac{(1/4 \times 1100)}{17748}}$

$f = 1.28\ Hz$

$\frac{1}{f} = 2\pi\sqrt{\frac{1100}{17748}}$

$f = 0.64\ Hz$

ResultsPlus
Examiner Comments

Q16(b)(i) 3 marks. The calculation is correct and a sufficient number of stages are included to satisfy the instruction to 'show that'. The answer is to the required extra significant figure for a 'show that' question.

Q16(b)(ii) 2 marks. The calculation is completed correctly on the left, including the require factor of four, but it is then repeated incorrectly on the right. The marks are given for the working, but not the final answer mark because if there are two answers, one answer is necessarily incorrect.

ResultsPlus
Examiner Tip

If you give more than one answer to a calculation, you cannot expect the examiner to choose the correct one for you. Even if you aren't sure which is correct, cross one of the final answers out.

(b) (i) Show that the stiffness of each spring is about $18000\,\mathrm{N\,m^{-1}}$.

(3)

$\Delta F = k \Delta x$

$F = mg = 1100 \times 9.81 = 10791\,\mathrm{N}$ (div by 4 for each wheel)

$\frac{\Delta F}{\Delta x} = \frac{10791 \div 4}{152 \times 10^{-3}} = 17700\,\mathrm{N\,m^{-1}}$

(ii) A force is applied to the car which results in a further small compression of each spring. The force is then removed, and the body of the car oscillates with simple harmonic motion.

Determine the frequency of the oscillations.

(3)

$T = 2\pi\sqrt{\frac{m}{k}} = 2\pi \times \sqrt{\frac{10791}{4 \times 17700}}$

$= 2.45\,\mathrm{s}$

$f = \frac{1}{T} = 0.41\,\mathrm{Hz}$

Frequency = 0.41 Hz

ResultsPlus
Examiner Comments

Q16(b)(i) 3 marks. Fully correct.

Q16(b)(ii) 1 mark. Weight has been used here instead of mass in this calculation of period. Although it is not strictly a time dimensionally, the mark has been allowed for 'use of $f = 1/T$'.

Question 16 (c)

Half of the candidates scored on this question, despite this being a straightforward set of conditions that should be memorised but, even if they are not, follow from the SHM formulae, $a = -\omega^2 x$, anyway.

Candidates often stated that acceleration is proportional to displacement but did not refer to displacement from the equilibrium position. Others referred to specific conditions for particular examples of SHM, such as within the elastic limit (already seen in (Q16(a)) or small angles. Other candidates referred to constant frequency, no energy loss, no external forces and so on.

(c) State the conditions for simple harmonic motion.

(2)

The initial displacement from equilibrium must be small, there should not be an external force are forcing the oscillations, the acceleration should always be towards equilibrium position.

ResultsPlus
Examiner Comments

1 mark. The mark is awarded for the last line. The other two conditions are not universal conditions for SHM. The small initial displacement is more relevant for a pendulum and a driving force at a matched frequency can be compatible with SHM.

(c) State the conditions for simple harmonic motion.

(2)

displacement moves in opposite direction to accelaration ~~acts to oppos~~

accelaraction is proportional to displacement

ResultsPlus
Examiner Comments

1 mark. The first line, despite the idea of displacement moving, is sufficient for the second mark, but the required reference to displacement 'from the equilibrium position' is missing, so no other mark.

(c) State the conditions for simple harmonic motion.

(2)

The acceleration of the body must be directly proportional and in the opposite direction to the displacement from it's equilibrium position. Energy is conserved at all points in the oscillation.

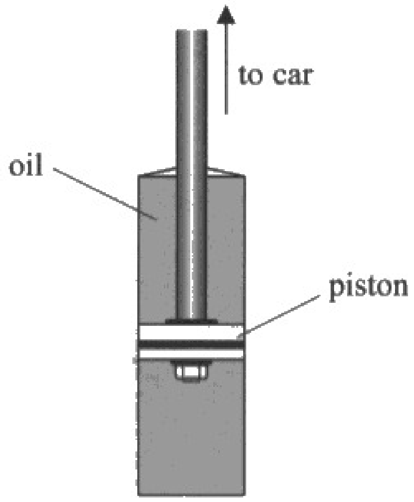
ResultsPlus
Examiner Comments

2 marks. The required conditions are given correctly and the extra one about energy is not actually contradictory, so the marks stand.

Question 16 (d)

The majority of candidates correctly referred to a large force, and a sizeable minority also stated that energy is dissipated quickly, this detail being missing from most other responses, but very few candidates mentioned work at all. In all cases, the relevant phenomenon required some qualification, **large** resistive force, **large** amount of work, energy dissipated **quickly**, and this was often the missing factor.

(d) The oscillations are heavily damped by a piston in the suspension system. The piston moves within a cylinder filled with oil, as shown. The oil has a high viscosity.



Explain why using oil of high viscosity will produce heavy damping.

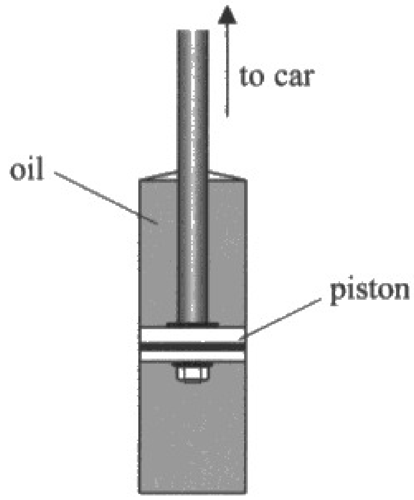
(3)

As the viscosity of the oil increases, the viscous drag produced by the oil increases. ~~to~~ When there is an oscillation, work is done by the piston against the oil which would disipate energy to the surroundings, ~~The~~ in the form of heat. This produces a slow ~~osci~~ decrease in the amplitude of the oscillation without any oscillations untill the amplitude is 0.

ResultsPlus
Examiner Comments

3 marks. This refers to drag, work and energy dissipation, but only the first of these are terms that clearly relate them to heavy damping when it says viscous drag increases. In fact, it even refers to a slow decrease in amplitude, which is not what heavy damping produces.

(d) The oscillations are heavily damped by a piston in the suspension system. The piston moves within a cylinder filled with oil, as shown. The oil has a high viscosity.



Explain why using oil of high viscosity will produce heavy damping.

(3)

$F = 6\pi \eta r v$

$F \propto \eta$

- resistive force is proportional to viscosity
- higher viscosity ∴ greater resistive force

∴ more work done against oscillation

∴ more energy dissipated in a shorter time

(Total for Question 16 = 12 marks)

∴ heavy damping.

ResultsPlus
Examiner Comments

3 marks. This correctly states greater resistive force, more work done and energy dissipated in shorter time.

Question 17 (a)

As well as their knowledge and understanding of diffraction gratings, this question assessed candidates' ability to give coherent and logically structured answers, which, in most cases, they did and were awarded all available 'linkage' marks.

The most common score for correct answers was 3 out of 6, and this was often either for the first three points, describing interference in general, possibly in one sentence, or the last three points, dealing with the resultant pattern. Few candidates dealt with both parts. Some high scoring responses were seen where the candidate had drawn a diagram showing the pattern produced, which made it easier to describe it in their explanation.

Answers often gave the impression that candidates weren't familiar with a diffraction grating pattern, seeming more like a Young's slits description.

The diffraction grating formula was often included, seemingly automatically, but was not often satisfactorily contextualised, sometimes just leading to 'red light is diffracted more' which does not include the required detail about the angle in the formula being the angle of the maximum of intensity.

Quite a few candidates thought blue light has a longer wavelength than red.

Candidates rarely referred to the colour seen when red and blue mix as magenta, more often calling it purple, probably thinking of mixing paints rather than light, or even violet, which is learned as a single spectral colour. These were not penalised, but they did represent a surprising regression from KS3 and GCSE knowledge and understanding.

17 Scientists can analyse light from stars that has passed through a diffraction grating.

*(a) Explain the pattern produced when a mixture of blue and red light, from the same source, passes through a diffraction grating.

(6)

- When the blue and red light passes through the diffraction grating, it spreads out
- The waves meet at a screen and interfere with eachother
- When the waves meet in phase, constructive superposition ~~interference~~ occurs and a position of maximum amplitude is formed
- When the waves meet in antiphase, destructive superposition occurs and a position of minimum amplitude forms
- The point where waves meet in phase is purple as maximum of blue and red colours mix,
- The point where waves meet in antiphase is green as a minimum amplitude of blue and red colours appear
- So a repeated pattern of ~~green~~ purple then green is formed

ResultsPlus
Examiner Comments

3 marks. This gets the first three IC points, but no more. The reference to red and blue making purple is not linked to the central maximum. 3 IC points score 2 marks and 1 mark is awarded for the structure and linkage, so 3 marks in total.

17 Scientists can analyse light from stars that has passed through a diffraction grating.

*(a) Explain the pattern produced when a mixture of blue and red light, from the same source, passes through a diffraction grating.

(6)

$n\lambda = d\sin\theta$

Since n and d are constant, and λ is different for blue and red light, with blue having the shorter wavelength, and red having a longer wavelength, so the $\sin\theta$ for blue light will be smaller than with the red light, so the blue light will be diffracted at a smaller angle compared to the red light.

ResultsPlus
Examiner Comments

2 marks. The marks here are in the second half of the IC points, specifically IC5 and IC6 for linking the wavelength to the angle of diffraction and applying it correctly to blue as having the shorter wavelength. Note that this says blue light is diffracted at a smaller angle and not just diffracted less, which was not sufficient when stated thus.

17 Scientists can analyse light from stars that has passed through a diffraction grating.

*(a) Explain the pattern produced when a mixture of blue and red light, from the same source, passes through a diffraction grating.

(6)

The diffraction grating will cause the light to spread out according to $n\lambda = d\sin\theta$. Since d is a constant as it depends on the diffraction grating, and red light has a longer wavelength than blue light, the red light will diffract by a greater angle than the blue light. ~~Both~~ Therefore the mixture of light will separate to form separate red and blue fringes. Fringes form due to constructive interference when waves meet in phase. The fringes of the red light will be more spread out than the fringes of the blue light since the diffraction angle is greater. Both colours of light will form a central maxima with no diffraction and so a purple central fringe will be seen.

ResultsPlus
Examiner Comments

6 marks. Relatively infrequent, but this is an example of a full mark response.

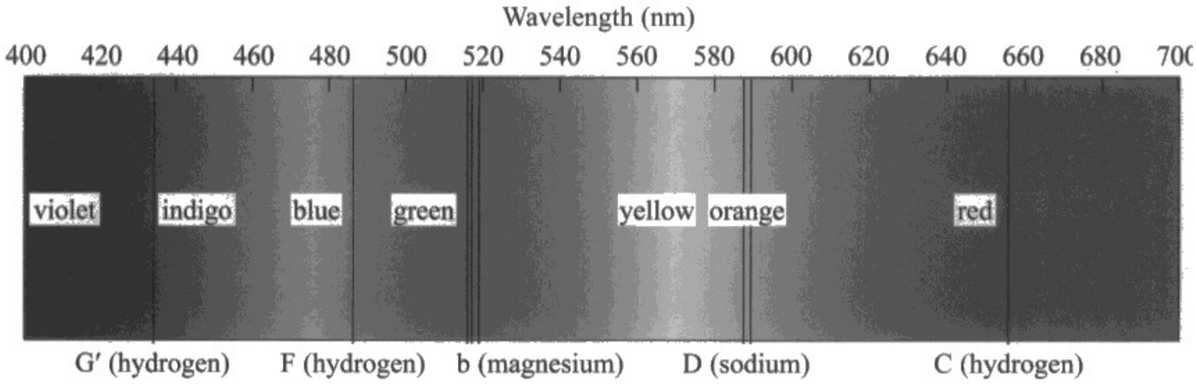
Question 17 (b)(i)

Generally, the likelihood of a particular mark being awarded decreased in the order of the marks in the mark scheme. Most candidates were awarded the first mark for including a statement about electrons existing in fixed energy levels. A good number went on to get the second mark for excitation following photon absorption, a number of those linked photon energy to the difference in energy levels and a proportion of those finally made the connection to the absorption of specific frequencies only.

Some candidates went on from the first mark to describe the formation of an emission spectrum rather than an absorption spectrum and gained no more marks. Others failed to mention photons at any stage.

When candidates referred to $E = hf$, they did not always make it clear that this referred to photon energy, so it could not contribute to the award of the final mark.

(b) A spectrum of the visible light emitted by a particular star is shown.



(Source: © Universal Images Group North America LLC/Alamy Stock Photo)

(i) Light interacts with atoms as it passes through the atmosphere of the star.

Explain how this leads to the formation of the dark lines within the spectrum.

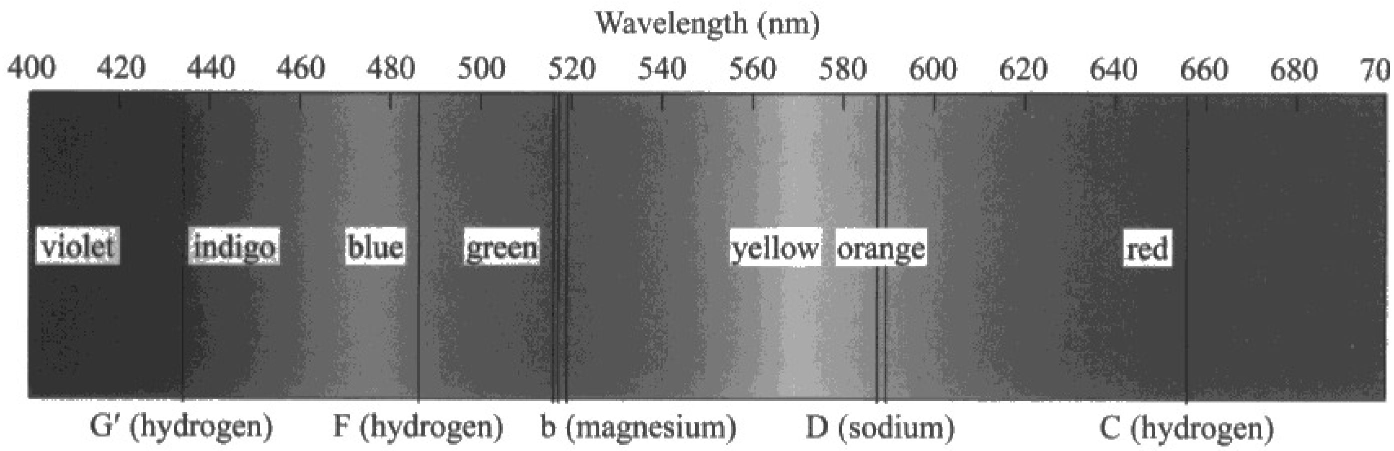
(4)

- photons of light interact with electrons.
- one to one interaction.
- electrons exist in discrete energy levels, hence only absorb certain photons.
- absorb energy and become excited.
- Immediately dexcite to lower level. discrete packet of energy.
- Release energy in form of photon.
- $\frac{E_1 - E_2}{h} = f$, as only certain energy levels, only certain frequency of light.
- $c = f\lambda$, hence $\frac{c}{f} = \lambda$, so only certain wavelengths of light emitted. Hence only certain colours are viewed.

ResultsPlus
Examiner Comments

2 marks. Discrete energy levels for electrons and excitation following photon absorption are correctly described, but the rest is about emission spectra.

(b) A spectrum of the visible light emitted by a particular star is shown.



(Source: © Universal Images Group North America LLC/Alamy Stock Photo)

DEMED (i) Light interacts with atoms as it passes through the atmosphere of the star.

Explain how this leads to the formation of the dark lines within the spectrum.

(4)

→ Electrons exist in discrete energy levels
→ Electrons move up energy levels absorbing a photon and becoming excited
→ when electrons move down energy levels they emit a photon.
→ The ~~diff~~ energy of the photon is equal to the change in energy levels
→ Hence there are certain energy changes and certain wavelengths on the spectrum.

ResultsPlus
Examiner Comments

3 marks. This deals with the first three marking points but does not make the final length to specific frequencies or wavelengths.

Question 17 (b)(ii)

The great majority of candidates were able to apply Wien's law to calculate the frequency of maximum intensity and about half of the entry drew a curve with the maximum at this position using the scale provided. Only about one in ten candidates drew the rest of the curve correctly, with the great majority starting their curve from zero intensity at a wavelength of zero and the curve generally being wider on the left than the right, rather than vice versa as required.

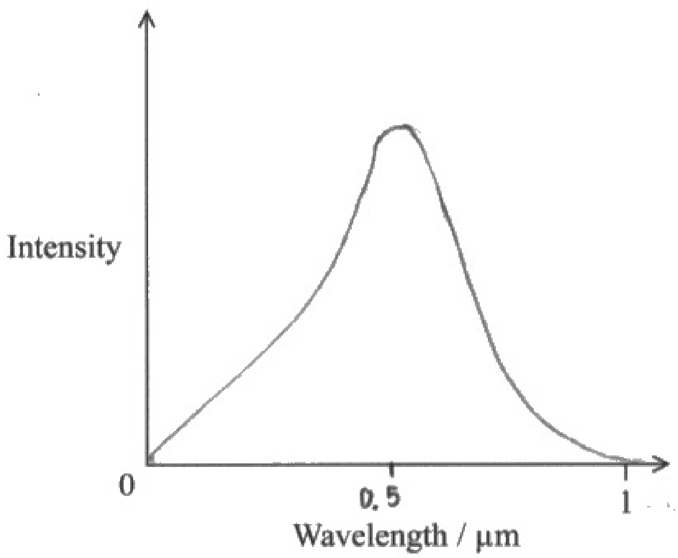
(ii) The surface temperature of the star is 5800 K.

On the axes below, sketch a graph of the intensity of radiation against the wavelength of that radiation for this star.

(4)

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

$\lambda_{max} = \frac{2.898 \times 10^{-3}}{5800} = 4.997 \times 10^{-7}\ \text{m} \approx 4.997\ \mu\text{m}$



ResultsPlus
Examiner Comments

3 marks. The calculation and peak are fine, but this curve is always wider on the left, so no final mark.

(ii) The surface temperature of the star is 5800 K.

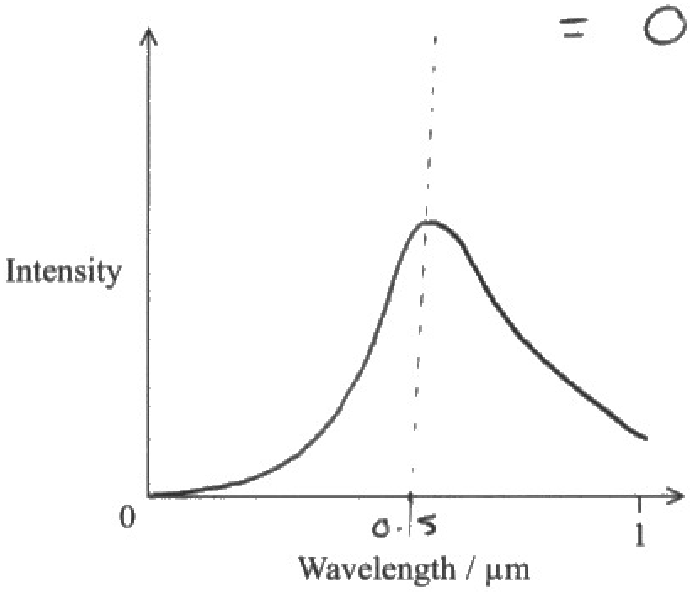
On the axes below, sketch a graph of the intensity of radiation against the wavelength of that radiation for this star.

(4)

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

$\lambda_{max} = \cancel{4.996}\ 5 \times 10^{-7}$ m

$= 0.5 \times 10^{-6}$ m



ResultsPlus
Examiner Comments

4 marks. Relatively rare, but this response fulfilled the requirements for the curve.

Question 17 (b)(iii)

The great majority of candidates were awarded the first marks for stating that fusion takes place. They often stated that this led to a force to balance gravitational forces, but only infrequently gave the required added detail that this was because of the energy released by fusion.

(iii) This star is a main sequence star.

Explain why main sequence stars do not collapse due to gravitational forces.

(2)

The fusion that occurs produces a ~~ke~~ force = to gravitational forces due to the large pressure caused by the fusion.

ResultsPlus
Examiner Comments

1 mark. A typical response, mentioning fusion, for 1 mark, and a force to balance gravitational forces, but not energy or high temperature.

(iii) This star is a main sequence star.

Explain why main sequence stars do not collapse due to gravitational forces.

(2)

Energy produced by fusion between hydrogen nuclei is sufficient to provide a force equal to the gravitational forces that try to Callapse it. Therefore they do not callapse as the forces are in equilibrium.

ResultsPlus
Examiner Comments

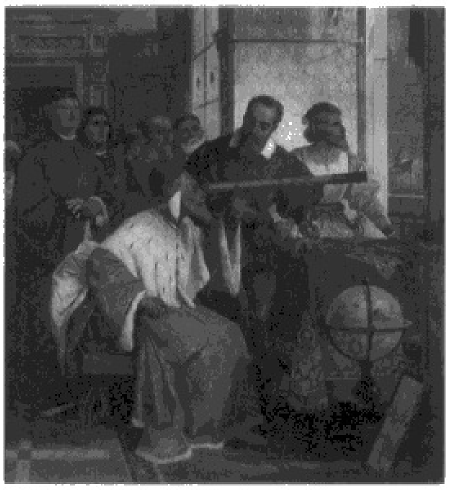
2 marks. An example of a response including all of the relevant points.

Question 18 (a)

A large number of candidates described their conclusions about the image rather than the object, for example that the image would be upside down or magnified etc. Those who deduced that the object was far away were most likely to explain it using the thin lens formula with $v = f$, reference to parallel rays was rarer.

The lack of familiarity with this situation suggests that candidates may not have much practical experience with lenses, and certainly not the quick method to obtain an approximate value of the focal length by focusing an image of outside the lab window.

18 Galileo is credited with inventing the first telescope in 1610. The picture shows an early demonstration of the telescope.



(Source: © CPA Media Pte Ltd/Alamy Stock Photo)

A converging lens was positioned at one end of the telescope. A diverging lens was placed at the other end and a person looked through this lens.

(a) The converging lens produced an image at a distance equal to the focal length of the lens.

Explain what can be concluded about the object being viewed.

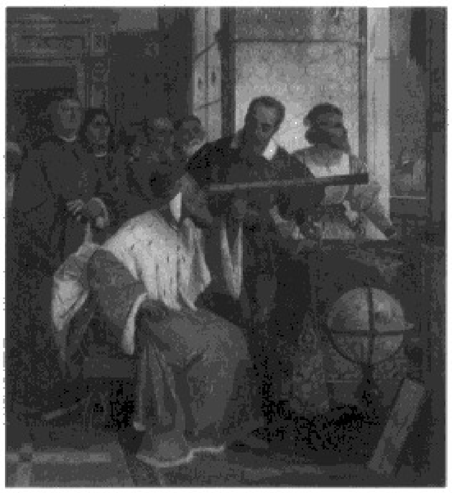
(2)

The object was futher than the focal length as it produced a real image. The object was very far away

ResultsPlus
Examiner Comments

1 mark. This response shows some recall of the effect of object distance relative to the focal length on image distance but does not support this in order to gain the other mark.

18 Galileo is credited with inventing the first telescope in 1610. The picture shows an early demonstration of the telescope.



(Source: © CPA Media Pte Ltd/Alamy Stock Photo)

A converging lens was positioned at one end of the telescope. A diverging lens was placed at the other end and a person looked through this lens.

(a) The converging lens produced an image at a distance equal to the focal length of the lens.

Explain what can be concluded about the object being viewed.

(2)

$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ $u \rightarrow \infty$ $\frac{1}{u} \rightarrow 0$ $\therefore \frac{1}{v} = \frac{1}{f}$ $\therefore v = f$

~~Object~~ Object is at infinity or at large distances away from lens.

ResultsPlus
Examiner Comments

2 marks. This response uses the lens formula to support the conclusion that the object is at infinity.

Question 18 (b)

Most candidates gained at least one mark, more frequently for ‘upright’, but only about a third gained both.

Those candidates not awarded the mark for 'virtual' often described the conditions for the formation of a virtual image, or referred to a position, eg on the same side of the lens as the object, rather than referring to the image not forming on a screen or the absence of rays passing through the point, as they would have learned when they first met virtual images in plane mirrors at Key Stage 3.

Those candidates not awarded the mark for 'upright' often simply stated ‘not inverted’ which is not a description of upright itself.

(b) The final image produced by the telescope is described as virtual and upright.

State what is meant by virtual and upright.

(2)

Virtual

It is not real

Upright

not upside down, correct way up

ResultsPlus
Examiner Comments

1 mark. Virtual as 'not real' is not sufficient as it is just the opposite version of the two options available. Similarly 'not upside down' would not be sufficient, especially as there are conceivably other orientations, but correct way up gets the mark.

(b) The final image produced by the telescope is described as virtual and upright.

State what is meant by virtual and upright.

(2)

Virtual

the image forms on the same side of the lens as the object

Upright

the image appears the same orientation as the object

ResultsPlus
Examiner Comments

2 marks. This is a good answer for upright, but the answer for virtual does not describe the nature of the image, merely a description of the circumstances in the situations where candidates have usually met it with lenses. In this telescope, the final image is on the other side of the lens to the intermediate image acting as an object, for example, and concave mirrors produce real images on the same side as the object.

Question 18 (c)

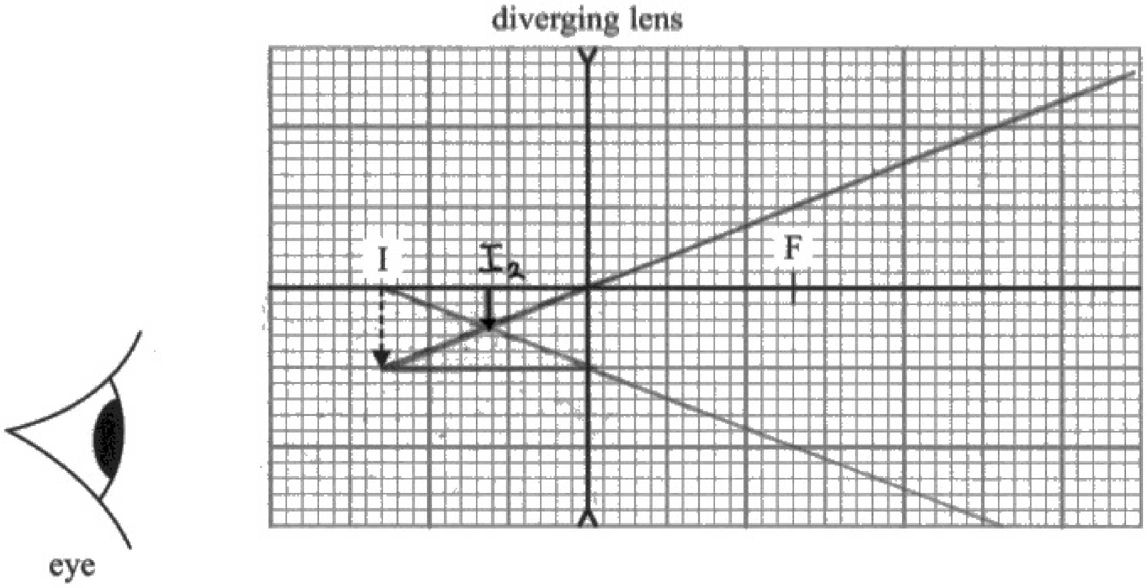
Most candidates completely ignored the position of the large eye in this diagram and drew rays going away from the image shown to the right of the diagram – away from the eye.

Some candidates treated the lens as a converging lens and drew the correct diagram for that situation, which is probably that with which they are most familiar, but incorrect in all respects except that of having a ray passing through the optical centre of the lens, for which they were awarded one mark.

Other candidates drew a correct diagram for a converging lens for light passing to the right and were also awarded the mark for the ray through the centre of the lens.

Some candidates gained an additional mark for drawing an arrow in the correct direction but very few completed the diagram correctly for 3 marks.

(c) The image, I, produced by the converging lens is at a distance from the diverging lens equal to the focal length of the diverging lens, as shown. This image acts as an object for the diverging lens.



The distance equal to the focal length on the other side of the lens is marked with F.

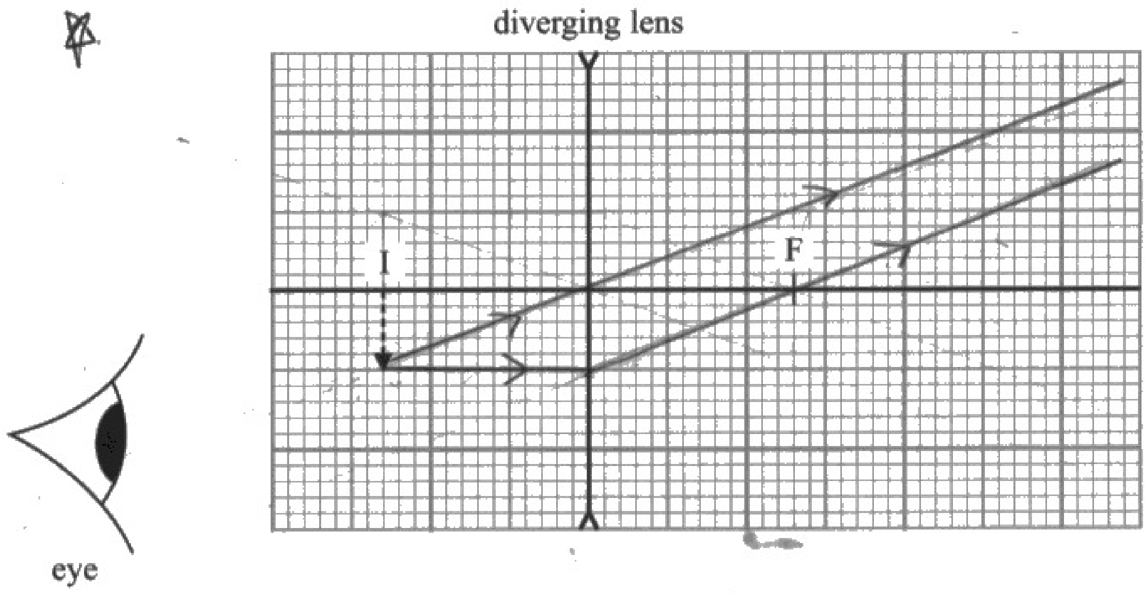
Draw the ray diagram for the diverging lens.

(3)

ResultsPlus
Examiner Comments

1 mark. This is a typical response. The ray diagram is what might be drawn for a real image on the left being viewed from the right. The mark is awarded for the ray through the optical centre of the lens that passes through the top of the image.

(c) The image, I, produced by the converging lens is at a distance from the diverging lens equal to the focal length of the diverging lens, as shown. This image acts as an object for the diverging lens.



The distance equal to the focal length on the other side of the lens is marked with F.

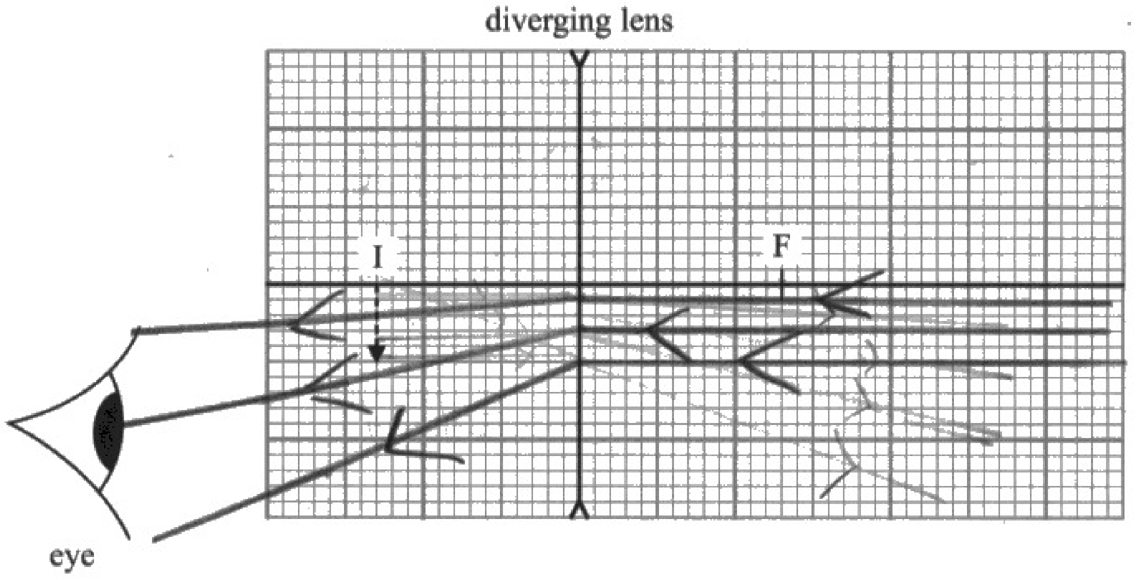
Draw the ray diagram for the diverging lens.

(3)

ResultsPlus
Examiner Comments

1 mark. One of the most common responses, this is actually the ray diagram in this situation for the light from the star at infinity forming the image at I, although the arrows are reversed. The ray through the centre is in the correct position for 1 mark.

(c) The image, I, produced by the converging lens is at a distance from the diverging lens equal to the focal length of the diverging lens, as shown. This image acts as an object for the diverging lens.



The distance equal to the focal length on the other side of the lens is marked with F.

Draw the ray diagram for the diverging lens.

(3)

ResultsPlus
Examiner Comments

2 marks. This is relatively rare, but the arrows are in the correct direction and the refraction is correct for rays parallel to the principal axis passing through the lens.

Question 18 (d)

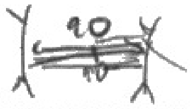
The diagram showed that the image was to the left of the diverging lens at a distance equal to the focal length of the diverging lens, the distance of the image from the converging lens was equal to the focal length of the converging lens and candidates were told that the distance from the diverging lens to the converging lens was 90 cm, so it should have been clear that $f_c = 90 + f_d$. Few candidates realised this, with those who did often doing so with the aid of a diagram showing the positions of the two lenses and the image. The majority of candidates approached it by assuming that the sum of the focal lengths was 90 cm, even though they knew that the focal point of the converging lens was not between the lenses. These candidates arrived at incorrect values of 81.8 cm and 8.18 cm, which did, at least, satisfy the magnification requirement given their incorrect assumption.

(d) Galileo's first telescope had a magnification of 10, and a distance between the centres of the two lenses of 90 cm.

The magnification of the telescope = $\dfrac{\text{focal length of converging lens}}{\text{focal length of diverging lens}}$ v / u

Calculate the focal length of each lens.

(2)



$mag = 10 = \dfrac{v}{u}$

$v + u = 90$

$10u = 90 - u$ $\qquad v = 90 - u.$

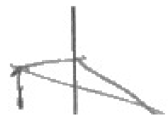
$10u + u = 90$ $\qquad v = 90 - \dfrac{90}{11}$

$11u = 90$ $\qquad v = \dfrac{900}{11}$ cm.

$u = \dfrac{90}{11}$ cm.

Focal length of converging lens = 81.8 cm

Focal length of diverging lens = 8.18 cm



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0 marks. This hasn't been badly done, apart from the initial step of making 90 cm the sum of the focal lengths.

(d) Galileo's first telescope had a magnification of 10, and a distance between the centres of the two lenses of 90 cm.

$$\text{The magnification of the telescope} = \frac{\text{focal length of converging lens}}{\text{focal length of diverging lens}}$$

Calculate the focal length of each lens.

(2)

$F_c = 90 + F_d$

$\frac{F_c}{F_d} = 10 \quad F_c = 10 F_d$

$10 F_d = 90 + F_d$

$90 = 9 F_d$

$F_d = 10$

Focal length of converging lens = 100 cm

Focal length of diverging lens = 10 cm

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Examiner Comments

2 marks. A very good, if rare, example of a fully correct response.

Question 18 (e)

Over half of the candidates scored at least 4 out of 5 marks, with two thirds of those completing it fully. Those candidates who derived a correct formula for *M* sometimes went astray with the orbital distance, failing to convert from km to m. Some candidates did not get as far as the correct formula because of an algebraic error in the rearrangement, most frequently due to incorrect cancelling of *r* or failing to square π. A more careful layout of the derivation would have helped many of these candidates.

(e) Galileo was the first person to observe Jupiter's larger moons.

Ganymede is Jupiter's largest moon. The distance between the centre of Ganymede and the centre of Jupiter is 1.07×10^6 km. Ganymede takes 171 hours to complete an orbit around Jupiter.

Calculate the mass of Jupiter. $r = 1.07 \times 10^6$

(5)

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

$$v^2 = \frac{GM}{r}$$

$$\frac{\cancel{m}(2\pi r)^2}{T^2} = \frac{GM}{r}$$

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

$$M = \frac{4\pi^2 r^3}{GT^2} = \frac{4\pi^2 \times (1.07 \times 10^6 \times 10^3)^3}{6.67 \times 10^{-11} \times 171 \times 60^2} = 1.18 \times 10^{33}$$

Mass of Jupiter = 1.18×10^{33} kg

(Total for Question 18 = 14 marks) (3 s.f.)

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Examiner Comments

3 marks. The formula for mass has been derived and the substitution includes a conversion of time to seconds, but time has not been squared. The power of two here is for seconds in an hour.

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Examiner Tip

When substituting in an equation with a power term, eg T^2, don't suddenly miss off the index when substituting or forget it in the calculation.

(e) Galileo was the first person to observe Jupiter's larger moons.

Ganymede is Jupiter's largest moon. The distance between the centre of Ganymede and the centre of Jupiter is 1.07×10^6 km. Ganymede takes 171 hours to complete an orbit around Jupiter.

Calculate the mass of Jupiter.

(5)

$F = \frac{Gm_1m_2}{r^2}$ $F = \frac{mv^2}{r}$ $\frac{Gm_1\cancel{m_2}}{r^{\cancel{2}}} = \frac{\cancel{m}v^2}{\cancel{r}}$ $v = \omega r$

$\omega = \frac{2\pi}{T} \Rightarrow v = \frac{2\pi r}{T}$

so $\frac{GM}{r} = \left(\frac{2\pi r}{T}\right)^2 \rightarrow T^2 = \cancel{\sqrt{\frac{4\pi^2 r^3}{GM}}}$ $M = \frac{4\pi^2 r^3}{GT^2}$

$M = 4\pi^2 \times (1.07 \times 10^6 \times 10^3)^3 / 6.67 \times 10^{-11} \times (171 \times 60 \times 60)^2$

$M = 1.91 \times 10^{27}$ kg

Mass of Jupiter = 1.91×10^{27} kg

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Examiner Comments

5 marks. The formula for mass has been derived correctly and fully substituted leading to a correct answer, including the correct unit – full marks awarded.

Paper Summary

Based on their performance on this paper, candidates should:

- Remember that physical quantities have a magnitude and a unit and both must be given in answers to numerical questions.
- Check that quantitative answers represent sensible values and go back over calculations when they do not.
- Learn standard descriptions of physical processes, such as atomic spectra or diffraction gratings, and be able apply them with sufficient detail to specific situations, identifying the parts of the general explanation required to answer the particular question.
- Ensure when asked to make a judgement or come to a conclusion by command words such as 'deduce whether', that you make a clear statement, including any values being compared.
- Remember that explanations can often be supported by reference to formulae on the data, formulae and relationships sheet, but you must make it clear what each symbol represents, eg in $E = hf$, E is the photon energy.
- Note that while diagrams may not, in themselves, be sufficient for marks they are to be encouraged when they help candidates to interpret the situation.
- Be sure to learn the correct meaning of the symbols in a given formula, not confusing similar symbols such as T for tension with T for time period or k for the Boltzmann constant with k for the Coulomb constant.
- Understand that while physics formulae are provided in the exam, the formulae for the circumference of a circle and volume of a cylinder must be remembered.

Grade boundaries

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

https://qualifications.pearson.com/en/support/support-topics/results-certification/grade-boundaries.html

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