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June 2022

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 applying ratios or converting °C to K. They also knew some significant points in explanations linked to standard situations, such as atomic spectra, 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 with most points included in ordered explanations of the situations in the questions.

Section A – multiple choice question

The percentages with correct responses for the whole cohort are shown in the table.

Question	Percentage of correct responses
1	51
2	34
3	30
4	46
5	64
6	57
7	78
8	43
9	45
10	75

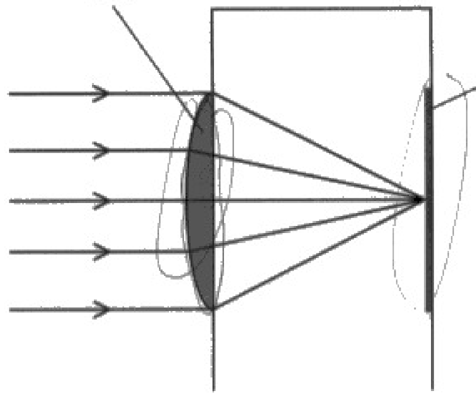
More details on the rationale behind the incorrect answers for each multiple choice question can be found in the published mark scheme.

Question 11 (a)

The majority of candidates applied the lens formula and calculated the image distance with ease, but only about one in eight went on to complete the question by calculating the displacement of the lens from its initial position. Most candidates gave the image distance as their answer without realising that anything else was required. Candidates should take care to read the question carefully, taking note of any key terms, possibly underlining or highlighting, to make sure that they answer fully. The fact that 4 marks were available for the question might also have suggested that a bit more than a single calculation was required.

A small proportion of candidates mixed the units of length for the different quantities, such as mm for focal length and cm for object distance. It is acceptable to use m, cm or mm but it must be the same unit throughout. Some candidates had difficulty with mm. Some had problems with signs when rearranging after substitution and a few forgot to apply the inverse having calculated $1/v$.

11 The lens of a mobile phone camera has a focal length of 4.25 mm. Light is focused onto light sensors at the back of the camera, as shown.



(a) The camera is initially focused on an object in the far distance.

Calculate the displacement of the lens that would be required to focus on an object 25.0 cm from the camera.

(4)

① focal length = 4.25mm

② $\frac{1}{f} = \frac{1}{u} + \frac{1}{v} \rightarrow \frac{1}{(4.25\times10^{-2})} = \frac{1}{v} + \frac{1}{(25\times10^{-2})}$

③ $\frac{1}{v} = \frac{1}{(4.25\times10^{-2})} - \frac{1}{(25\times10^{-2})} = 19.529$ m

④ $v = \frac{1}{19.529} = 0.0512$m

Displacement of lens = 0.0512 m

ResultsPlus
Examiner Comments

1 mark awarded.

There has been an error with the power of ten for mm, so this is treating the focal length as cm.

There has not been an attempt to calculate displacement.

ResultsPlus
Examiner Tip

In questions with mixed quantities, be sure to convert all values to the same SI units.

(a) The camera is initially focused on an object in the far distance.

Calculate the displacement of the lens that would be required to focus on an object 25.0 cm from the camera.

(4)

$f = 4.25\,mm$ or $0.0425\,cm$ $\quad \frac{1}{f} = \frac{1}{u} + \frac{1}{v}$

$\frac{1}{0.425} = \frac{1}{25} + \frac{1}{u} \quad \frac{1}{u} = 2.31 \quad u = 0.433\,cm$

Displacement of lens = 0.00433m

ResultsPlus
Examiner Comments

2 marks awarded.

This shows a straightforward calculation of the image distance, but this is given as the final answer, totally ignoring the reference to displacement in the question.

ResultsPlus
Examiner Tip

Be sure to note key terms in the question and address them all in your response.

Question 11 (b)

Having missed the displacement calculation in the first part of the question, candidates missed an important piece of information relating to the answer here. Those who calculated the displacement had seen that *v* differed little over a wide range of object distances, but the great majority didn't have this clue. A common suggestion was that the lens would change shape. Another was that it would be dealt with by 'autofocus' while some simply stated that it had to be at a fixed distance in order to fit in the phone.

0 marks awarded.

(b) State why the lens and the light sensors in a mobile phone camera can be positioned a fixed distance apart.

(1)

Mobile phone lenses can vary there power/focal length

ResultsPlus Examiner Comments

Quite a few candidates made unsupported suggestions such as this statement.

0 marks awarded.

(b) State why the lens and the light sensors in a mobile phone camera can be positioned a fixed distance apart.

(1)

The displacement required is very small.

ResultsPlus Examiner Comments

This is correct and relevant but isn't developed sufficiently for credit.

1 mark awarded.

(b) State why the lens and the light sensors in a mobile phone camera can be positioned a fixed distance apart.

(1)

because as the object distance is usually much greater than the focal length the image distance ≈ the focal length

(Total for Question 11 = 5 marks)

ResultsPlus
Examiner Comments

This is an example of a response that meets the requirement of the question.

Question 12

The majority of candidates were able to apply an equation derived from Newton's law of gravitation, but often this was for gravitational field strength rather than for gravitational potential as required.

A common error among those setting out on the correct approach of calculating the potential at the two positions and multiplying the difference by mass was using altitude instead of distance from the centre of the planet. Some candidates only calculated potential or the change in potential and missed out the step of multiplying by the mass of the satellite. Some candidates used the mass of the satellite while calculating potential. Where candidates were attempting to apply gravitational potential, they used distance squared as the denominator.

The most common incorrect approach was to apply *mgh*, calculating *g* for Mars using the radius or one of the heights and then assuming it was constant during the descent. This would give the correct answer to 2 s.f., but in order to be awarded full marks candidates needed to justify the approach by stating that *g* would be approximately constant over the range of altitudes considered. A similar approach seen occasionally was to calculate the gravitational force on the satellite and use work = force x distance.

0 marks awarded.

12 In February 2021 the spacecraft Perseverance Rover landed on Mars. When the spacecraft was 11.0 km above the surface of Mars, parachutes opened to slow the descent. The parachutes detached from the spacecraft when it was 2.1 km above the surface of Mars.

Calculate the change in gravitational potential energy of the spacecraft during the parachute section of its descent.

mass of spacecraft = 1030 kg
mass of Mars = 6.39×10^{23} kg
radius of Mars = 3390 km

$E_{grav} = mgh$

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

$= \frac{6.67 \times 10^{-11} \times 6.39 \times 10^{23}}{(~~11.0~~ + 3390)^2 \times 10^3}$

$= 3.71\ ms^{-2}$

$E = 1030 \times 3.71 \times 2100$

$= 8022567$

$= 8020000\ J$

Change in gravitational potential energy of the spacecraft = 8.02×10^6 J

ResultsPlus
Examiner Comments

This shows the value of *g* at the surface of Mars being calculated. The application of *mgh* is not allowed for the second mark because it is for a single position and not a change in height.

2 marks awarded.

Calculate the change in gravitational potential energy of the spacecraft during the parachute section of its descent.

mass of spacecraft = 1030 kg
mass of Mars = 6.39×10^{23} kg
radius of Mars = 3390 km

$g = \frac{Gm}{r^2} = \frac{6.67\times10^{-11} \times 6.39\times10^{23}}{(3,390,000)^2}$

$= 3.71$

GPE = mgh

$= (1030 \times 3.71 \times 11,000) - (1030 \times 3.71 \times 2,100)$

$= 33.988 \times 10^6$ J

Change in gravitational potential energy of the spacecraft = 34 MJ

ResultsPlus
Examiner Comments

In this example *mgh* has been used, but without any acknowledgement that it is not constant over the range. It gives the correct answer to 2 s.f. so it is a reasonable approximation and 2 marks are awarded.

2 marks awarded.

Calculate the change in gravitational potential energy of the spacecraft during the parachute section of its descent.

mass of spacecraft = 1030 kg
mass of Mars = 6.39×10^{23} kg
radius of Mars = 3390 km

$GPE = -\frac{GMm}{r}$

~~$\Delta V = -\frac{GM}{r} + \frac{GM}{r}$~~

$\Delta GPE = -\frac{GMm}{r_1} + \frac{GMm}{r_2} = -GMm\left(\frac{1}{11\times10^3} - \frac{1}{2.1\times10^3}\right)$

$= -6.67\times10^{-11} \times 1030 \times 6.39\times10^{23}\left(\frac{1}{11\times10^3} - \frac{1}{2.1\times10^3}\right)$

$= 1.69\times10^{13}$ J

Change in gravitational potential energy of the spacecraft = 1.69×10^{13} J

ResultsPlus
Examiner Comments

The correct approach is being taken, but the distances used are the altitudes rather than the distance from the centre of the planet, so the answer is incorrect.

ResultsPlus
Examiner Tip

When answering questions about gravitation applied to satellites or similar situations, be sure to differentiate between distance above the surface of a planet and distance from the centre of the planet.

Question 13

The majority of candidates were able to demonstrate some knowledge and understanding of radioactive decay, but far greater success in this was achieved by those applying a more explicitly mathematical approach rather than a descriptive approach as the latter tended to lack detail. Fully numerical solutions were the clearest of all.

Most candidates could apply the idea of half-life correctly to at least one of the isotopes and many were able to apply decay constant = ln 2 / half-life. The missing part in many responses was making the final step linking decay constant and number of nuclei to activity.

Where candidates calculated the decay constant, some made a bit more work for themselves by using seconds whereas days are acceptable for this comparative answer where the actual activity couldn't be calculated because the number of nuclei wasn't known.

1 mark awarded.

13 Actinium-225 and bismuth-210 are radioactive isotopes. A sample of each isotope is prepared so that each sample has the same number of nuclei initially.

Explain why the activity of each sample would be the same after 10 days.

half-life of actinium-225 = 10 days
half-life of bismuth-210 = 5 days

$A = \lambda N$. Initially N is the same for both samples. For the first 5 days, there would be more activity from bismuth since its λ is greater: $\lambda = \frac{\ln 2}{t_{1/2}} = \frac{\ln 2}{5}$. However, its N value would be a lot smaller than that of Actinium after those first 5 days, meaning Actinium's activity would be greater for the final 5 days. This variation will even out so after 10 days, the activity of both would appear to be the same.

ResultsPlus
Examiner Comments

This response shows a largely descriptive explanation which is hard to follow and does not make the required explanation. It gets a single mark for applying the decay constant equation.

4 marks awarded.

The decay constant of Actinium (λ_1) is $\frac{\ln 2}{10}$ days^{-1}, and the decay constant of Bismuth (λ_2) is $\frac{\ln 2}{5}$ days^{-1}. So λ_2 is double λ_1. Both have the same number of nuclei (N_0) initially.

$\therefore N_1 = N_0 e^{-10\lambda_1} = N_0 e^{-\ln 2} = \frac{N_0}{2}$

So $A_1 = \lambda_1 \times \frac{N_0}{2}$.

$N_2 = N_0 e^{-10\lambda_2} = N_0 e^{-2\ln 2} = \frac{N_0}{4}$

So $A_2 = \lambda_2 \times \frac{N_0}{4} = 2\lambda_1 \times \frac{N_0}{4} = \lambda_1 \frac{N_0}{2} = A_1$

$\therefore A_1 = A_2$ [A_1 and A_2 are the activities of actinium and bismuth, respectively, after 10 days]

ResultsPlus Examiner Comments

This response shows the clarity achieved by a more mathematical description.

ResultsPlus Examiner Tip

Explanations can often be supported by reference to formulae on the data, formulae and relationships sheet.

Question 14 (a)

Only a minority of candidates scored for this question because they made simple statements such as 'as wavelength increases, change in wavelength increases' without stating proportionality. Some included the idea of proportionality but didn't support it with reference to the red shift equation. Some stated (change in wavelength) / wavelength = *z*, but didn't clarify that *z* is constant.

1 mark awarded.

(a) Explain why the long wavelength lines are shifted by a greater amount than the short wavelength lines.

(2)

Redshift is occuring so $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$ $\frac{v}{c}$ is constant as v is speed of star which doesn't change for different wavelength so for larger λ which is wavelength there needs to be a greater shift as a greater shift represents a greater change in wavelength – in order for $\frac{v}{c}$ to remain constant

ResultsPlus
Examiner Comments

This is all correct, but further detail was required, describing the proportional relationship between wavelength and change in wavelength.

2 marks awarded.

(a) Explain why the long wavelength lines are shifted by a greater amount than the short wavelength lines.

(2)

From the redshift equation: $\Delta\lambda = z\lambda$. z is a constant ratio, which depends on the star's relative speed. So $\Delta\lambda$ is directly proportional to λ. So for longer wavelengths, λ is greater, so $\Delta\lambda$ is greater, so the wavelength lines are shifted more.

ResultsPlus Examiner Comments

An example of a response with sufficient detail.

Question 14 (b)

The majority of candidates were able to estimate the wavelength of the line in Spectrum B and apply it to the red shift equation, although some only calculated *z* and didn't use it for velocity. A fair number completed the calculation correctly but didn't include a statement about direction in their conclusion.

1 mark awarded.

(b) One of the lines in the hydrogen spectrum occurs at a wavelength of 656 nm in the laboratory.

Explain what conclusion can be made from the shift in wavelength of this line in spectrum B. Your answer should include a calculation.

(4)

Shift to the right of the spectrum means redshift which would mean that the distant star is moving away from us.
$Z = \frac{\Delta\lambda}{\lambda} \approx \frac{\Delta f}{f} \approx \frac{v}{c}$. It is shifting towards the longer waves in the EM wave spectrum.

ResultsPlus
Examiner Comments

This gets a mark for stating the direction of the relative motion, but the instruction to include a calculation has not been followed.

ResultsPlus
Examiner Tip

Read questions carefully and be sure to carry out all instructions given.

4 marks awarded.

(b) One of the lines in the hydrogen spectrum occurs at a wavelength of 656 nm in the laboratory.

Explain what conclusion can be made from the shift in wavelength of this line in spectrum B. Your answer should include a calculation.

(4)

• The redshift (Z) can be calculated, if the wavelength from the lab and from spectrum B, that correspond to the same energy transfer by electrons in each star are known and recorded.

• The redshift can be used to find the stars recessional velocity relative to earth as $Z = \frac{v}{c}$

• $\lambda_2 = \left(700 + \left(\frac{1.3}{4.35} \times 100\right)\right)$ nm = 729.885 nm

• ∴ $Z = \frac{\Delta\lambda}{\lambda} = \frac{729.885 - 656}{656} = 0.1126297 = \frac{v}{c}$

• ∴ $V = 0.1126297 \times (3 \times 10^8) = 3.38 \times 10^7$ m s^{-1}

∴ The velocity of the star relative to earth is 3.38×10^7 m s^{-1}

(Total for Question 14 = 6 marks)

ResultsPlus
Examiner Comments

The calculation has been completed giving an answer within the required range. While there is no statement of the direction, the reference to recessional velocity is sufficient.

Question 15

The majority of candidates scored at least 4 marks out of the 6 available for this question. A few only applied one of latent heat and specific heat capacity, but most included both in their calculation of the energy required to melt the aluminium. While the majority could calculate the mobile phone energy, there was a lower general level of success in applying the 5% factor correctly to calculate the energy saved.

Among those who successfully completed all five steps in the calculations, a disappointing minority did not make an explicit comparison of the calculated quantities in their final conclusion.

4 marks awarded.

15 Aluminium is one of the most widely recycled metals. Aluminium cans are heated from room temperature until all the aluminium has melted. The molten aluminium is then used to make new cans. This process uses only 5% of the energy needed to extract aluminium from raw materials.

On a website it is claimed that recycling one aluminium can of mass 14 g saves enough energy to listen to music on a mobile phone continuously for 7 days.

Assess the validity of this claim.

melting point of aluminium = 660 K
specific heat capacity of aluminium = 902 J kg^{-1} K^{-1}
specific latent heat of aluminium = 396 kJ kg^{-1}
room temperature = 293 K
mobile phone p.d. = 3.7 V
mobile phone current = 120 mA

Energy into can 367

$\Delta E = mc\Delta\theta = 0.014 \times 902 \times (660 - 293) = 4634.5$

$\Delta E = L\Delta m = 396 \times 0.014 = 5.544$

$\Sigma E = 4640 J$ 0.05 of total

total energy $= 4640 \times \frac{1}{0.05} = 92800 J$

Phone energy

$E = IVt = 120 \times 10^{-3} \times 3.7 \times 7 \times 24 \times 3600 = 268531 J$

saved ↓ Phone energy ↓

$92800 > 268531$

This claim is valid. ~~assuming~~
Since the energy saved is greater than used by phone.

(Total for Question 15 = 6 marks)

ResultsPlus Examiner Comments

The energy calculations are correct, but the percentage applied is 100 rather than 95, so the answer is incorrect and only 4 marks have been awarded.

6 marks awarded.

$E_{heat\ Al} = mc\Delta\theta + mL$

$= (14\times10^{-3})(902)(660-293) + (14\times10^{-3})(396\times10^{3})$

$= \underline{10178.5\ J}$

energy saved by recycling $= \frac{(10178.5)}{0.05} \times 0.95 = 193391.5$

$E_{phone} = P \times t$

$= IV \times t$

$= 3.7\times(120\times10^{-3}) \times (7\times24\times3600)$

$= \underline{268531\ J}$

$193391.5\ J < 268531\ J$

So the statement is not valid.

ResultsPlus Examiner Comments

This is fully correct. A comparison of the final values has been made, as required, for a numerical question asking candidates to 'assess the validity', and a clear conclusion has been made.

Question 16 (a-b)

In Q16(a) the majority of candidates drew a suitable line and used the gradient to determine a value within the required range. A minority drew their line to pass through the point (50, 0.0), perhaps thinking of the many graphs they have met that demonstrate direct proportionality, although that was not the case here and that point was not even (0,0). Most candidates used a sensible triangle for their gradient, but some were small enough to cause their answer to fall outside the range. Candidates should ensure that their gradient triangle is as large as possible while choosing points that are easy to read. They should also be sure to use the line rather than the plotted points.

Some candidates misread the scale, for example reading a value of 1.55 eV as 1.6 eV because they took one small square to be 0.1 eV. This error in the value of a small division is best avoided by making sure to look at the labelled scale value above the point as well as the value below.

In Q16(b) most candidates were able to at least make a good start, with greater success when using the *f* intercept rather than a point on the line. There were some candidates using a point on the line who didn't convert eV to J at the right stage.

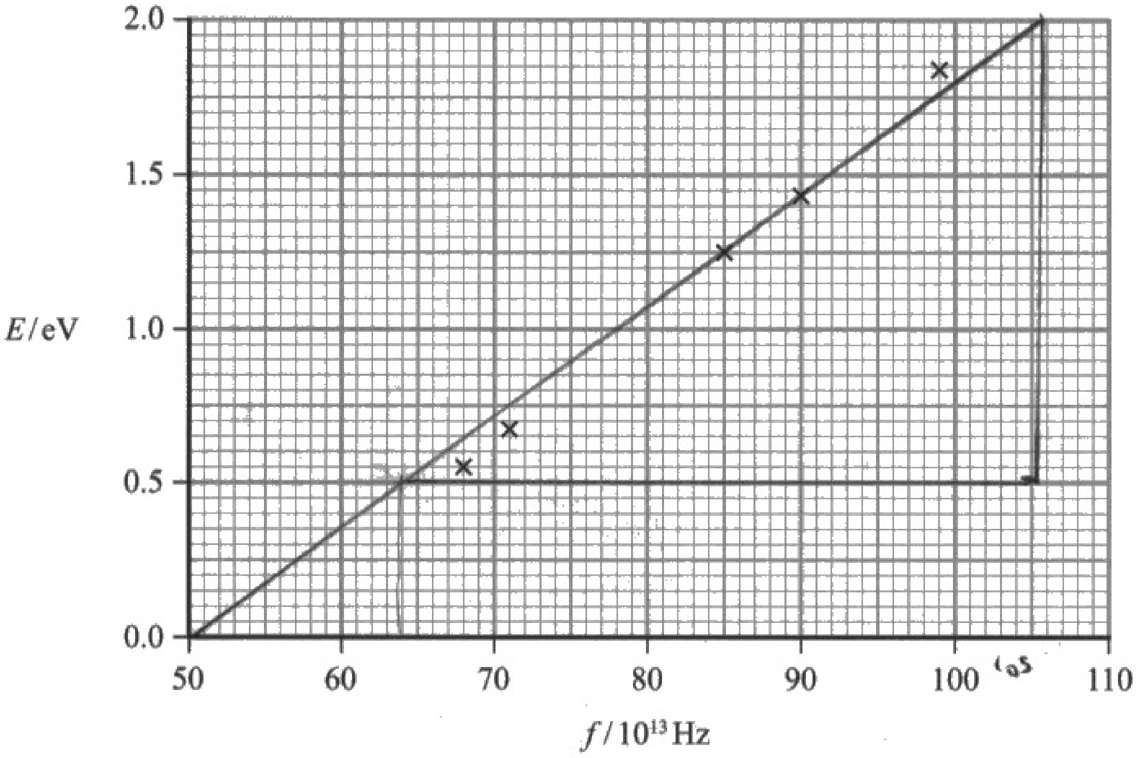
Some candidates calculated the work function correctly but didn't apply it to the table to deduce which metal was being used.

Q16(a) 2 marks awarded.

Q16(b) 1 mark awarded.

16 In an investigation of the photoelectric effect, electromagnetic radiation of frequency f was directed onto a metal plate. The maximum kinetic energy E of the photoelectrons emitted from the metal plate was determined. The procedure was repeated for a range of frequencies.

The graph shows how E depended upon f.



(a) Determine a value for the Planck constant, h, in J s.

(4)

$E = hf$ $h = \frac{\Delta E}{\Delta f}$ = gradient   Energy in J

Gradient of graph = $\frac{2.0 \times 1.6 \times 10^{-19} - 0.5 \times 1.6 \times 10^{-19}}{106 \times 10^{13} - 64 \times 10^{13}} = 5.7 \times 10^{-34}$ Js

$h =$ 5.7×10^{-34} J s

(b) The table gives data for different metal surfaces. Caesium $E_{k\,max} = ...$

Metal surface	Work function / eV
Caesium	2.0
Calcium	2.9
Magnesium	3.7

Deduce which metal was being used in the investigation.

(3)

$\phi = hf_0$

$hf = \phi + E_{k\,max}$

Caesium: $f_0 = \frac{2 \times 1.6 \times 10^{-19}}{6.63 \times 10^{-34}} = 4.8 \times 10^{14}\ Hz = 480 \times 10^{13}\ Hz$

Calcium: $f_0 = \frac{2.9 \times 1.6 \times 10^{-19}}{6.63 \times 10^{-34}} = 6.9 \times 10^{14}\ Hz$

Magnesium: $f_0 = \frac{3.7 \times 1.6 \times 10^{-19}}{6.63 \times 10^{-34}} = 8.9 \times 10^{14}\ Hz$

(Total for Question 16 = 7 marks)

$hf > \phi$ so that photoelectrons can have kinetic energy.

$f > f_0$

so Caesium must have been used

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Q16(a) - the line is not the best-fit as it has been forced through the apparent origin.

The gradient triangle could have been larger, which reduces the percentage uncertainty in the calculated value, but it is sufficient. The conversion has been made from eV to J.

Q16(b) - this response shows the threshold frequency for each metal, which is an acceptable approach, but the basis for the conclusion that the metal is caesium has not been made clear.

ResultsPlus
Examiner Tip

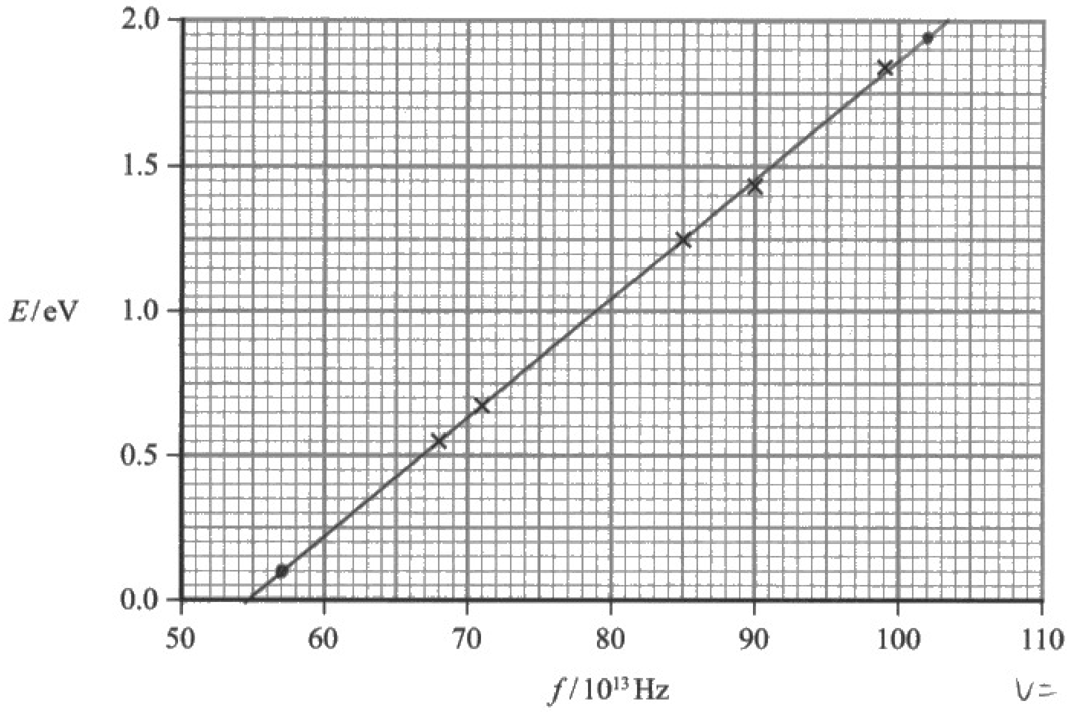
Make sure that the triangle used for calculating the gradient is as large as possible to ensure accuracy in the answer.

Q16(a) 4 marks awarded.

Q16(b) 3 marks awarded.

16 In an investigation of the photoelectric effect, electromagnetic radiation of frequency f was directed onto a metal plate. The maximum kinetic energy E of the photoelectrons emitted from the metal plate was determined. The procedure was repeated for a range of frequencies.

The graph shows how E depended upon f.



(a) Determine a value for the Planck constant, h, in J s.

(4)

$v = f\lambda$

$f = \frac{1}{s}$

$E = \phi + \frac{1}{2}mv^2$ gradient = h

$E = hf + \frac{1}{2}mv^2$

h = gradient = $\frac{eV}{f}$ = $\frac{eV}{\frac{1}{s}}$ = eVs

gradient = $\frac{1.95 - 0.1}{(102 - 57) \times 10^{13}}$ = 4.11×10^{-15} eVs

h in eVs

but in Js = $4.11 \times 10^{-15} \times 1.6 \times 10^{-19}$

= 6.58×10^{-34}

h = 6.58×10^{-34} J s

(b) The table gives data for different metal surfaces.

Metal surface	Work function / eV
Caesium	2.0
Calcium	2.9
Magnesium	3.7

Deduce which metal was being used in the investigation.

(3)

threshold frequency ≈ 55×10^{13} Hz

$E = hf$ $= 55 \times 10^{13} \times 6.63 \times 10^{-34}$

$\approx 3.64 \times 10^{-19}$

in eV

$= \frac{3.64 \times 10^{-19}}{1.6 \times 10^{-19}} = 2.275$ eV

≈ 2.3 eV

so ~~Calcium as~~ Caesium as Calcium wouldn't cause photo emissions at 2.3eV.

(Total for Question 16 = 7 marks)

ResultsPlus Examiner Comments

Full marks have been awarded for both parts. The points used for the gradient are close to the maximum separation and have been chosen to be easy to read and not between lines.

Question 17 (a)(i)

A majority of candidates failed to score here. Many of the successful answers had additions to the diagrams indicating the focal length of each lens. Having parallel rays that weren't parallel to the principal axis is, perhaps, an unusual situation that they didn't connect to focal length in the way they would have done for a GCSE ray diagram.

Mathematical treatments to show $v = f$ for the objective lens and $u = f$ for the eyepiece lens were generally clearer than descriptive answers.

1 mark awarded.

(a) (i) In the arrangement shown, the final image is formed at infinity.

Explain why the separation of the objective and eyepiece lenses is equal to the sum of their focal lengths.

(2)

$\frac{1}{u} + \frac{1}{v} = \frac{1}{f}$ $\quad v = \infty \quad \frac{1}{v} \to 0$

$\frac{1}{u} = \frac{1}{f}$

$u = f$ so, the separation of the objects (the lenses) must be equal to the sum of their ~~focal~~ focal lengths.

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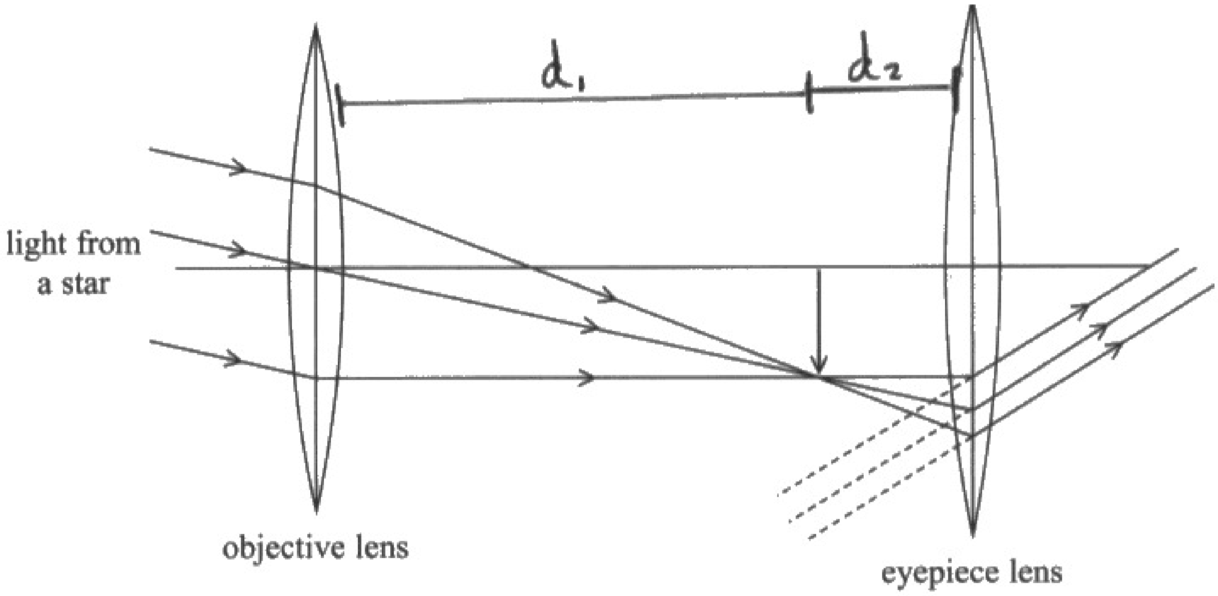
Although it isn't stated, this calculation applies to the eyepiece lens. A bit more commentary would be required to apply similar reasoning to the objective lens.

2 marks awarded.



(a) (i) In the arrangement shown, the final image is formed at infinity.

Explain why the separation of the objective and eyepiece lenses is equal to the sum of their focal lengths.

(2)

- The rays hit the first lens parallel to each other
- So the distance marked d_1 is the first lens's focal length *
- The rays leave the second lens parallel to each other
- So the distance marked d_2 is the second lens's focal length
- So the distance between the lenses is equal to the sum of their focal lengths.

ResultsPlus Examiner Comments

This is an example of a good response for this question, with additions to the diagram helping to clarify the explanation.

Question 17 (a)(ii)

Only a minority of candidates gave answers that gained credit for this question. There were quite a few references to real and virtual images, but not in a way that was relevant here.

0 marks awarded.

(ii) State why the final image is inverted.

(1)

~~it is a real image~~ the rays from star get flipped in the eyepiece lens.

ResultsPlus
Examiner Comments

This nearly scores, but the location of the 'flipped' rays is incorrect.

1 mark awarded.

(ii) State why the final image is inverted.

(1)

Because the 'object' it is an image of is also ~~at in~~' inverted and as it is a virtual image at infinity it has the same orientation as whatever it is an image

ResultsPlus
Examiner Comments

While this isn't a full explanation, as it doesn't tell us why the intermediate image is inverted, it is true and sufficient for the mark.

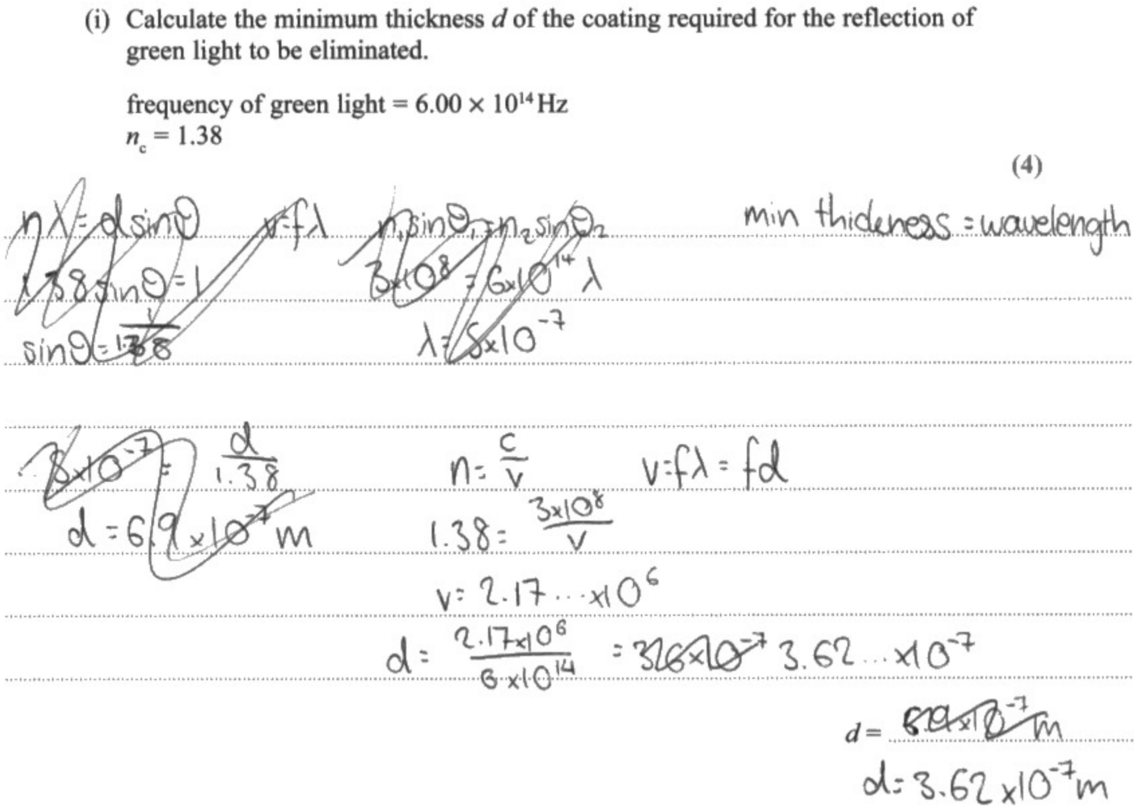
Question 17 (b)(i)

Having been told that the situation involves interference, candidates knew that they needed to consider wavelength and most could apply the refractive index to calculate the speed of light in the coating and the wavelength of green light, although some just used the wavelength in air.

A few then attempted to apply the diffraction grating equation, even though there was no angle and no line spacing.

The problem for most candidates was applying a factor of 2 twice – once for the path difference and once for the reflection.

2 marks awarded.


(i) Calculate the minimum thickness d of the coating required for the reflection of green light to be eliminated.

frequency of green light = 6.00×10^{14} Hz

$n_c = 1.38$

(4)

min thickness = wavelength

$n = \frac{c}{v}$ $\quad v = f\lambda = fd$

$1.38 = \frac{3\times10^8}{v}$

$v = 2.17\ldots\times10^6$

$d = \frac{2.17\times10^6}{6\times10^{14}} = 3.62\ldots\times10^{-7}$

$d = 3.62\times10^{-7}$ m

ResultsPlus
Examiner Comments

The wavelength of the light in the coating has been calculated correctly, but the candidate has suggested that this should be equal to thickness for destructive interference, so no further marks have been awarded.

3 marks awarded.

(i) Calculate the minimum thickness d of the coating required for the reflection of green light to be eliminated.

frequency of green light = 6.00×10^{14} Hz
$n_c = 1.38$

(4)

$f\lambda = c \quad \lambda = \frac{c}{f} = \frac{3\times10^8}{6\times10^{14}} = 5\times10^{-7}$ m.

To interfere destructively : path difference = $\frac{\lambda}{2}$.

or phase difference = π. $T = 1.67\times10^{-15}$

∴ Time taken for light to ~~x~~ enter coating and reflect off the lens is $\frac{1}{2}\times1.67\times10^{-15}$. $V = \frac{c}{1.38}$, $v = 2.174\times10^8$

$2d = 2.174\times10^8 \times \frac{1}{2}\times1.67\times10^{-15}$

$2d = 1.815\times10^{-7}$

$d = 9.08\times10^{-8}$

$d = 9.1\times10^{-8}$

$V = \frac{d}{t}$

$d = vt$.

ResultsPlus
Examiner Comments

All of the calculation is correct, but the unit has not been included with the final answer so the final mark has not been awarded.

ResultsPlus
Examiner Tip

Physical quantities have a magnitude and a unit and both must be given in answers to numerical questions.

Question 17 (b)(ii)

It would appear from responses seen that candidates believe white light is made of purple and green so that, once green is removed, only purple remains. Quite a few didn't link the idea of destructive interference to this situation, despite the earlier part.

0 marks awarded.

(ii) State why white light reflected from coated lenses is seen as purple.

(1)

Due to the green lenses absorbing the green wavelengths in the white light only reflecting purple

(Total for Question 17 = 8 marks)

ResultsPlus
Examiner Comments

This is a typical response, lacking in detail and apparently forgetting what was learned about the visible spectrum at Key Stage 3.

1 mark awarded.

(ii) State why white light reflected from coated lenses is seen as purple.

(1)

green light is eliminated so the light reflected is a mixture of red and blue which appears purple

(Total for Question 17 = 8 marks)

as there are still wavelengths from either end of the visible spectrum.

ResultsPlus
Examiner Comments

This is one of the better responses seen.

Question 18 (a)(i-ii)

In Q18(a)(i) most candidates quickly realised the relationship between mass per unit length, density and area, and condensed the two equations into mass per unit length = rho x A and, as a result, got full marks.

In Q18(a)(ii) most candidates knew that they needed to apply the formula for the speed of a transverse wave on a string and started with the wave speed. Many candidates, however, did not correctly apply the factor of two to calculate the wavelength, some simply used the length of the string and some halved it. This led to the common award of two marks.

In some cases, candidates using the formula for the speed of a transverse wave on a string took *T* to be period of oscillation and used the frequency to calculate this.

Q18(a)(i) 2 marks awarded.

Q18(a)(ii) 2 marks awarded.

(a) (i) Show that the mass per unit length μ of the string is about $1.1 \times 10^{-3}\,\text{kg}\,\text{m}^{-1}$.

(2)

density = ~~volume~~ cross-sec. area / mass per unit length.

cross sectional area of string = $\pi \left(\frac{1.14}{2} \times 10^{-3}\right)^2$

mass per unit length μ = $1.021 \times 10^{-6} \times 1070$

$= 1.09 \times 10^{-3} \approx 1.1 \times 10^{-3}$ kgm^{-1}

(ii) When the middle of the string is plucked, a note of frequency 440 Hz is produced.

Calculate the tension in the string.

length of string = 41.0 cm

(4)

$v = f\lambda$ $\quad f\lambda = \sqrt{\frac{T}{\mu}}$ $\quad$ length of string = 41 cm.

middle of string = 20.5 cm

= 440 × 0.205

= 90.2 $\quad 90.2 = \sqrt{\frac{T}{\mu}}$ $\quad T = 90.2^2 \times 1.1 \times 10^{-3}$

= 8.95 N.

Tension in string = 8.95 N.

ResultsPlus
Examiner Comments

Q18(a)(i) - this part is fine for both marks.

Q18(a)(ii) - the length has been halved to find the wavelength when it should have been doubled. In this situation, it could have helped to visualise the situation with the use of a diagram.

Q18(a)(i) 2 marks awarded.

Q18(a)(ii) 4 marks awarded.

(a) (i) Show that the mass per unit length μ of the string is about $1.1 \times 10^{-3}\,kg\,m^{-1}$.

(2)

$\frac{M}{l} = \frac{\rho V}{l} = \frac{\rho A l}{l} = \rho A = \rho \frac{\pi d^2}{4}$

$= 1070 \times \frac{\pi \times (0.14 \times 10^{-3})^2}{4} = 1.092152695 \times 10^{-3}\,kg\,m^{-1}$

$\approx 1.1 \times 10^{-3}\,kg\,m^{-1}$

(ii) When the middle of the string is plucked, a note of frequency 440 Hz is produced.

Calculate the tension in the string.

length of string = 41.0 cm

(4)

$f = \frac{1}{2L}\sqrt{\frac{T}{\mu}}$

$440 = \frac{1}{2 \times 0.41} \times \sqrt{\frac{T}{1.1 \times 10^{-3}}}$

$360.8 = \sqrt{\frac{T}{1.1 \times 10^{-3}}}$

$130176.64 = \frac{T}{1.1 \times 10^{-3}}$

$T = 143.194304\ N$

$\approx 140\ N$

Tension in string = 140N

ResultsPlus
Examiner Comments

Q18(a)(i) - this has been very well explained.

Q18(a)(ii) - full marks for a straightforward calculation.

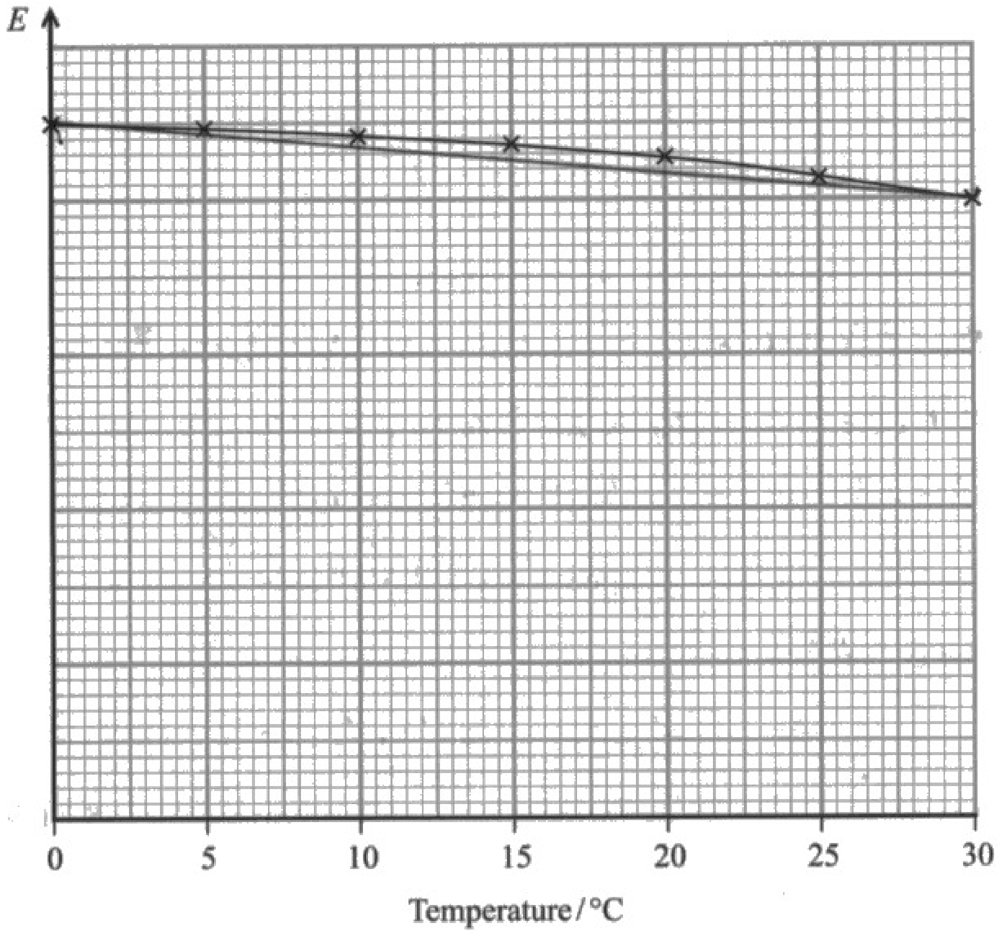
Question 18 (b)

The majority of candidates were able to note from the graph that the Young modulus decreases with temperature, although a surprising number did not make this elementary observation. Most of those who did were able to state that the tension would then decrease, although some candidates thought that the strain would increase so the length would increase.

While many candidates stated that the frequency would then decrease, they did not always link this to decreasing wave speed or mention that the wavelength is unchanged.

0 marks awarded.

(b) The graph shows how the Young modulus E of the nylon varies with temperature.



When the harp is played, the temperature of the string increases.

Explain how this temperature change would affect the frequency of the note produced when the string is plucked.

(3)

$E = hf$

$E \propto f$, Greater frequency would create a higher pitch for the harp.

$f = \frac{1}{T}$ ∴ frequency is inversely proportional to temperature

As the temperature increases, the frequency decreases

ResultsPlus
Examiner Comments

While correctly applied formulae can help greatly with explanations, in this case letters from the graph have been applied to incorrect quantities leading to incorrect relationships. In particular, a formula with T for time period has been used with T for tension leading to the correct final conclusion, but unsupported by any relevant evidence.

ResultsPlus
Examiner Tip

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 E for photon energy with E for the Young modulus.

2 marks awarded.

Temperature / °C

When the harp is played, the temperature of the string increases.

$E = \frac{fl}{ea}$

Explain how this temperature change would affect the frequency of the note produced when the string is plucked.

(3)

As the temperature increases, the young modulus of the string decreases. This means it will extend more for the same force. This will reduce the tension in the string so the frequency of the note will decrease as λ is constant.

ResultsPlus
Examiner Comments

This is largely correct, except for saying that the string extends more.

2 marks awarded.

When the harp is played, the temperature of the string increases.

Explain how this temperature change would affect the frequency of the note produced when the string is plucked.

(3)

As the temperature increases ~~young~~ the young modulus decreases, so a ~~greater~~ smaller stress would need to be applied to ~~a~~ achieve the same strain / extension in the string. This means that more energy would be transferred to wire when it is plucked with a given force and frequency of note produced ~~of the~~ would increase.

ResultsPlus
Examiner Comments

This is going well up to decreased stress, but, in common with some other candidates, this candidate appears to think there is a direct link between temperature and the energy transferred to the wire and therefore the frequency.

Question 19 (a)

This question presented no general difficulty and a majority scored full marks. A few candidates didn't convert to Kelvin and some had problems calculating volume, either using an area formula or using the diameter value as a radius value. A few candidates may have simply found a formula that worked in the situation without full understanding because they used the Coulomb law constant for *k* instead of the Boltzmann constant.

1 mark awarded.

19 A fine-beam tube is used for investigating properties of electrons.

An electron beam is produced inside a spherical glass bulb. The bulb contains neon gas at a very low pressure.

(a) The neon gas is at a pressure of 1.25 Pa and a temperature of 25 °C.

Calculate the number *N* of neon atoms inside the bulb.

bulb diameter = 16.0 cm

(4)

$pV = NkT$

$1.25 \times \frac{4}{3}\pi \times \left(\frac{16\times10^{-2}}{2}\right)^2 = N \times 1.38\times10^{-23} \times (25+273)$

$N = 8.15\times10^{18}$ neon atoms

$N =$ 8.15×10^{19} (3 s.f.)

ResultsPlus
Examiner Comments

Quite a few candidates, as in this example, did not know the formula for a sphere. In this case there is a length squared, so it is dimensionally an area and cannot be credited for use as a volume.

ResultsPlus
Examiner Tip

While physics formulae are provided in the exam, the formulae for the circumference and radius of a circle and area and volume of a sphere must be remembered.

2 marks awarded.

19 A fine-beam tube is used for investigating properties of electrons.

An electron beam is produced inside a spherical glass bulb. The bulb contains neon gas at a very low pressure.

(a) The neon gas is at a pressure of 1.25 Pa and a temperature of 25 °C.

Calculate the number N of neon atoms inside the bulb.

bulb diameter = 16.0 cm

(4)

$pV = NkT \qquad V = \frac{4}{3}\pi \times (0.16)^3$

$N = \frac{pV}{kT}$

$= \frac{1.25 \times \frac{4}{3}\pi(0.16)^3}{1.38 \times 10^{-23} \times (25+273)}$

$= 5.22 \times 10^{18}$ particles (3sf)

$N = 5.22 \times 10^{18}$

ResultsPlus
Examiner Comments

The diameter of the sphere has been used without halving to find the radius. It is a volume, so its use in the gas equation has been credited, along with the correct use of Kelvin.

ResultsPlus
Examiner Tip

Whenever you are given the diameter of a circle or sphere, look carefully to decide whether you need to use the radius in the following calculation.

4 marks awarded.

(a) The neon gas is at a pressure of 1.25 Pa and a temperature of 25 °C.

Calculate the number N of neon atoms inside the bulb.

bulb diameter = 16.0 cm

(4)

$pV = NkT$

$\therefore N = \frac{pV}{kT} = \frac{1.25 \times \frac{1}{6}\pi \times (16.0 \times 10^{-2})^3}{1.38 \times 10^{-23} \times (25 + 273)}$ *

$= 6.5188... \times 10^{17}$

$= 6.52 \times 10^{17}$ (3sf)

$N = 6.52 \times 10^{17}$ atoms

* Since $V = \frac{4}{3}\pi r^3 = \frac{4}{3}\pi\left(\frac{d}{2}\right)^3 = \frac{4}{3}\pi \times \frac{d^3}{8} = \frac{1}{6}\pi d^3$

ResultsPlus Examiner Comments

The candidate has made the volume calculation a bit more complicated than necessary, but it is correct.

Question 19 (b)

As well as their knowledge and understanding of atomic spectra, this question assessed candidates' ability to give coherent and logically structured answers, which, in most cases, they did.

Only one in twenty of the candidates scored full marks here, with the rest evenly divided between 0 and 5 marks.

Most candidates were able to successfully explain the processes of excitation and de-excitation of an electron and the subsequent release of a photon. Many candidates recognised that energy levels were discrete and included this in their explanations.

Candidates did not link the energy of the photon to the difference in energy levels as frequently.

A large majority failed to link the energy absorbed by the electron to the electrons interacting with the neon atoms, with some candidates describing thermal excitation and others linking excitation to the absorption of photons.

The final link between the limited number of specific energy changes and the associated specific frequencies was not generally made with sufficient clarity.

4 marks awarded.

Explain the process that results in the emission of this spectrum. Your answer should include reference to energy levels in atoms.

(6)

Electrons exist in discrete energy levels and are excited by neon atoms. The electrons can jump up Energy levels only if they gain the exact amounts of energy needed to reach that specific energy level. When they have jumped the energy levels, they become unstable and move back down to their ground state, however can jump between the different energy levels in any order. At the same time, they release photons with the energy equal to that of the difference between energy levels with a constant frequency, $E=hf$. E & h are constant and so is f & ∴ so is λ as $c=f\lambda$.

ResultsPlus
Examiner Comments

This includes the indicative content points 2, 3, 4 and 5. The mechanism of excitation is not included and the final link to the appearance of specific wavelengths is not made. The use of the word 'jumped' should be noted. It is sufficient in line 2 because it goes on to say 'up'. The same would apply for 'down' for de-excitation. 'Jumped' alone is not sufficient.

6 marks awarded.

Explain the process that results in the emission of this spectrum. Your answer should include reference to energy levels in atoms.

(6)

When an electron from the electron beam collides with a neon atom, some of the kinetic energy from the electron is used to excite an electron within the neon atom from its ground state to a higher energy level. ~~Its~~ Within the neon atom, the energy levels that an electron can occupy are discrete and specific to the neon atom, so when an electron is excited, ~~to~~ it has absorbed a specific amount of energy equal to the difference in energy between its ground state and the higher energy level. Then, deexcitation occurs, and the electron in the neon atom returns to its ground state, either directly or by transferring to multiple lower energy levels. As ~~the~~ one electron moves down an energy level, one photon is emitted with energy equal to the difference between the higher and lower energy levels. The wavelength and frequency of an emitted photon depend on its energy ($E = hf$); since there are specific energy levels in the atom, the emitted photons can only have certain frequencies, and these specific wavelengths show up as the bright lines on the spectrum - it is not continuous because not all wavelengths are emitted.

(Total for Question 19 = 10 marks)

ResultsPlus Examiner Comments

This is a good example of a full mark question, with all the indicative content points well-structured to show a sustained line of reasoning.

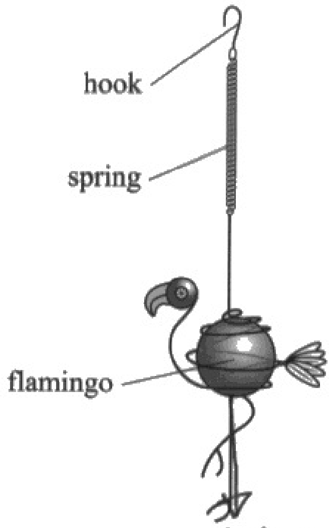
Question 20 (a)

A good majority worked though this sequence of calculations straightforwardly to a correct result, including a comparison and conclusion that the statement is incorrect. Some candidates used the formula for the period of a pendulum, using the extension of the spring as the length.

Other errors included powers of 10 with the mass or the extension and not using *g* to calculate weight from mass.

1 mark awarded.

20 A garden ornament consists of a metal flamingo suspended from a spring as shown. The spring is hung from a support using the hook.



$x = 8.5\text{cm}$

$Mg =$

(a) The mass of the flamingo is 65 g. When the flamingo is suspended vertically the spring extends by 8.5 cm.

The flamingo is pulled downwards by a small extra displacement and then released. The flamingo undergoes simple harmonic motion vertically.

The instructions state that the flamingo will oscillate with a frequency of 2.5 Hz.

Deduce whether this statement is correct. $f = \frac{1}{T}$

(5)

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

$mgh = \frac{1}{2}mv^2$

$9.81 \times 0.085 = \frac{1}{2}v^2$

$v = 1.29\,\text{ms}^{-1}$

$v = \frac{2\pi r}{T} \rightarrow T = \frac{2\pi r}{v} = \frac{2\pi(8.5 \div 2 \div 100)}{1.29}$

$= 0.207\,\text{s}$

$f = \frac{1}{T} = \frac{1}{0.207} = 4.83\,\text{Hz}$

$\neq 2.5\,\text{Hz}.$

ResultsPlus Examiner Comments

In this response, conservation of energy has been used to derive a speed and this has been used with a circular motion equation to derive a time period. The mark is for using this time period to calculate a frequency.

5 marks awarded.

(a) The mass of the flamingo is 65 g. When the flamingo is suspended vertically the spring extends by 8.5 cm.

The flamingo is pulled downwards by a small extra displacement and then released. The flamingo undergoes simple harmonic motion vertically.

The instructions state that the flamingo will oscillate with a frequency of 2.5 Hz.

Deduce whether this statement is correct.

(5)

$F = kx$

$0.065 \times 9.81 = k \times 0.085$

$k = 7.5018$

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

$= 2\pi\sqrt{\frac{0.065}{7.5018}}$

$= 0.58486$

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

$= 1.71$ Hz

∴ statement is not correct.

ResultsPlus
Examiner Comments

This is a straightforward example of a full mark response, including a conclusion.

Question 20 (b)

A majority of candidates gained some credit for this question, with a large majority scoring both marks. While damping or resistive forces were often mentioned, there were a lot of general references to 'energy lost' without sufficient detail for the second mark.

1 mark awarded.

(b) After being set into vertical oscillation, the flamingo comes to rest after a short time.

Explain why the flamingo comes to rest.

(2)

The motion is damped by resistive forces, such as drag

ResultsPlus Examiner Comments

This starts with a correct statement about the situation but does not go on to explain how it relates to the flamingo coming to rest. A simple response like this would be appropriate when the command word is 'state', but 'explain' will always have two distinct parts at the very least.

ResultsPlus Examiner Tip

Be sure you know the command words and understand the level of required response for each of them, eg 'explain' would mean a candidate must include the relevance of a statement about a situation and not just state it. There will always be at least two linked marking points for a question asking you to 'explain'.

2 marks awarded.

(b) After being set into vertical oscillation, the flamingo comes to rest after a short time.

Explain why the flamingo comes to rest.

(2)

→ it is not a perfect system

→ energy is dissipated [illegible] into the seroundings in the form of [illegible] heat (kenetic energy given to serounding particles due to resistive forces e.g. air resistance)

ResultsPlus
Examiner Comments

This response includes the two linked points as required.

Question 20 (c)(i-ii)

In Q20(c)(i) only a few candidates were unable to successfully calculate the period, occasionally due to forgetting to take a square root.

In Q20(c)(ii) about half of the candidates completed this part correctly. Quite a few used the correct equation for velocity for simple harmonic motion but didn't just assume that the maximum value for sine is 1, using a value for time in their calculation. Where this time was the period that was fine, but some found other values to substitute.

Q20(c)(i) 2 marks awarded.

Q20(c)(ii) 2 marks awarded.

(c) In a slight breeze the flamingo swings from side to side and behaves as a simple pendulum.

(i) Show that the period of oscillation of the flamingo pendulum is about 2.2 s.

pendulum length = 1.25 m

(2)

$T = 2\pi \frac{\sqrt{L}}{\sqrt{g}}$

$T = \frac{2\pi \times \sqrt{1.25}}{\sqrt{9.81}} = 2.243\,s$

(ii) The amplitude of oscillation of the flamingo pendulum is 7.5 cm.

Calculate the maximum velocity of the flamingo pendulum.

(3)

$a = 0.075 \qquad 0.446 \times 2\pi = \omega = 2.801242$

$\frac{1}{2.243} = f = 0.446$

$v = -A\omega \sin \omega t$

$v = -0.075 \times 2.8 \times \sin(2.8 \times 2.243)$

$= -0.21 \sin(6.2836) = -0.023\,ms^{-1}$

Maximum velocity = $0.023\,ms^{-1}$

ResultsPlus
Examiner Comments

Q20(c)(i) - this part is correct and the answer is quoted to at least one s.f. more than the 'show that' value of 2.2 s, as required.

Q20(c)(ii) - this is very nearly correct, but by using actual values of time and angular velocity with sine the answer differs slightly from that required. Candidates should know that the maximum value of sine is 1.

Q20(c)(i) 2 marks awarded.

Q20(c)(ii) 3 marks awarded.

(c) In a slight breeze the flamingo swings from side to side and behaves as a simple pendulum.

against friction.

(i) Show that the period of oscillation of the flamingo pendulum is about 2.2 s.

pendulum length = 1.25 m

(2)

$T = 2\pi\sqrt{\frac{1.25}{9.81}} = 2.24\ s$

$\approx 2.2\ s$

(ii) The amplitude of oscillation of the flamingo pendulum is 7.5 cm.

Calculate the maximum velocity of the flamingo pendulum.

(3)

$x = 0.075\text{m} \cos\left(\frac{2\pi}{2.24\text{s}} t\right)$

$v = -0.075\left(\frac{2\pi}{2.24\text{s}}\right)\sin\left(\frac{2\pi}{2.24\text{s}} t\right)$

$v_{max} = (0.075)\left(\frac{2\pi}{2.24}\right) = 0.21\ \text{ms}^{-1}$

Maximum velocity = 0.21ms^{-1}

ResultsPlus
Examiner Comments

This whole section gets full marks. The candidate was following a similar route to the previous example but realised that the maximum value for sine is 1 and used that rather than coming up with a time.

Question 21 (a)

Most candidates completed the equation with four correct numbers, but a few made a mistake in either the top line or the bottom line or both. The most common errors were to use a positive atomic number for the beta particle or to reverse the figures for the beta particle.

0 marks awarded.

21 A hundred years ago, a method to determine the age of certain rocks was developed. An unstable isotope of rubidium is present in some rocks when they form. Over time the rubidium decays to a stable isotope of strontium.

(a) Rubidium decays to strontium via β^- decay. Complete the nuclear equation representing the decay.

$$ {}^{88}_{37}\text{Rb} \rightarrow {}^{87}_{37}\text{Sr} + {}^{1}_{0}\beta^- + \bar{\nu}_e $$

ResultsPlus Examiner Comments

Fully incorrect responses were rare. This response shows a correct application of totalling atomic numbers and mass numbers, but they have been assigned incorrectly to the beta particle, so the answers are incorrect.

1 mark awarded.

21 A hundred years ago, a method to determine the age of certain rocks was developed. An unstable isotope of rubidium is present in some rocks when they form. Over time the rubidium decays to a stable isotope of strontium.

(a) Rubidium decays to strontium via β^- decay. Complete the nuclear equation representing the decay.

$$ {}^{87}_{37}\text{Rb} \rightarrow {}^{87}_{36}\text{Sr} + {}^{0}_{-1}\beta^- + \bar{\nu}_e $$

ResultsPlus Examiner Comments

The top row is correct, but not the bottom row.

Question 21 (b)

More than half of the candidates scored 2 or more marks here. Most could apply the decay constant calculation and the decay equation, but the ratio proved a bit more difficult. About a tenth of the candidates calculated the correct answer but only scored 4 marks out of 5 because they didn't make a clear comparison of their calculated answer with a value from the question and make a valid conclusion.

5 marks awarded.

(b) A sample of Moon rock from the Apollo 11 mission was analysed to determine the age of the rock. When the sample was analysed the number of rubidium atoms was N_R and the number of strontium atoms was N_S.

As strontium atoms have all been produced from the decay of rubidium, the original number of rubidium atoms in the sample was $(N_R + N_S)$.

From the analysis of the sample, it was determined that $\frac{N_S}{N_R} = 0.0532$

Deduce whether this ratio is consistent with the Earth and the Moon forming at the same time.

age of Earth = 4.5×10^9 years

half-life of rubidium isotope = 4.88×10^{10} years

(5)

$N = N_0 e^{-\lambda t}$ $\quad \lambda = \frac{\ln 2}{4.88 \times 10^{10}}$ years

$N_0 = N_R + N_S$

$N_R = (N_R + N_S) e^{-\frac{\ln 2}{4.88 \times 10^{10}} t}$

$N_S = 0.0532 N_R$

so $N_R + N_S = 1.0532 N_R$

so $\frac{1}{1.0532} = e^{-\frac{\ln 2}{4.88 \times 10^{10}} t}$

so $\ln 1.0532 = \frac{\ln 2}{4.88 \times 10^{10}} t$

$t = 3.6 \times 10^9$ years.

$3.6 \times 10^9 < 4.5 \times 10^9$ hence [illegible]

The ratio is inconsistent.

![ResultsPlus Examiner Comments]

ResultsPlus
Examiner Comments

There were two main routes to answering this question. This is a correct example based on the time calculation. The calculation has been completed and the relevant comparison and conclusion made at the end.

5 marks awarded.

(b) A sample of Moon rock from the Apollo 11 mission was analysed to determine the age of the rock. When the sample was analysed the number of rubidium atoms was N_R and the number of strontium atoms was N_S.

As strontium atoms have all been produced from the decay of rubidium, the original number of rubidium atoms in the sample was $(N_R + N_S)$.

From the analysis of the sample, it was determined that $\frac{N_S}{N_R} = 0.0532$

Deduce whether this ratio is consistent with the Earth and the Moon forming at the same time.

age of Earth = 4.5×10^9 years
half-life of rubidium isotope = 4.88×10^{10} years

(5)

$\lambda = \frac{\ln 2}{t_{1/2}} = \frac{\ln 2}{4.88 \times 10^{10} \times (365 \times 24 \times 3600)}$ ~~$= 4.5 \times 10^{-19}$~~ $= 1.42 \times 10^{-11}\ y^{-1}$

$N = N_0 e^{-\lambda t}$

~~$N = (N_R + N_S) e^{-(4.5 \times 10^{-19}) \times}$~~

$N_R = (N_R + N_S) e^{-(1.42 \times 10^{-11}) \times (4.5 \times 10^9)}$

$N_R =$ ~~0.9384~~ $0.938 N_R + 0.938 N_S$

$0.0619 N_R = 0.938 N_S$

$\frac{N_S}{N_R} = \frac{0.0619}{0.938} = 0.0660$

$\neq 0.0532$

$\therefore$ not consistent

ResultsPlus
Examiner Comments

There were two main routes to answering this question. This is a correct example based on the ratio calculation. The calculation has been completed and the relevant comparison and conclusion made at the end.

Question 21 (c)

Only about one in eight candidates gave a satisfactory answer here. Many responses demonstrated that candidates had the incorrect idea that the half-life could only be measured by measuring the time for the activity to decrease by half directly, making irrelevant comparisons with a human lifetime or the age of the Earth or other imprecise statements.

0 marks awarded.

(c) Give a reason why the half-life of the rubidium isotope is hard to determine.

(1)

it is ~~long~~ greater than the age of the moon or the Earth hence very large and decaying very slowly

ResultsPlus
Examiner Comments

This is a fairly typical response just based on the length of the half-life. Decaying very slowly isn't enough as it doesn't relate specifically to a measurable quantity.

1 mark awarded.

(c) Give a reason why the half-life of the rubidium isotope is hard to determine.

(1)

Its activity is extremely low so it decays very slowly and takes a long time to lose a substantial proportion of its mass.

ResultsPlus
Examiner Comments

This describes a possible method of determining the half-life related to change in mass due to the decay. The question suggests that the mass of the isotope might be measurable, although it actually describes measurement of a ratio of two isotopes. The response goes beyond those that just say it decays slowly.

0 marks awarded.

(c) Give a reason why the half-life of the rubidium isotope is hard to determine.

(1)

It is very long so people over many generations would have to continue an experiment to find its half life

ResultsPlus
Examiner Comments

This is an interesting idea, but it is just saying that it would take a long time.

Question 21 (d)

A large minority of candidates gained credit for stating that a larger half-life would mean a smaller decay constant, but they did not all clearly demonstrate how this would affect the calculated age. Those referring to the decay equation at this point were in a much better position than those attempting a purely descriptive explanation.

1 mark awarded.

(d) Recent investigations suggest that the half-life of the rubidium isotope may be larger than the traditionally accepted value.

Explain how this would affect the ages obtained by this dating method.

(2)

λ will be smaller for a larger $t_{1/2}$, so the ages calculated would actually be greater, i.e. the sample of moon rock is older.

ResultsPlus
Examiner Comments

This response states that the decay constant will be smaller, but doesn't link this to the age in sufficient detail.

2 marks awarded.

(d) Recent investigations suggest that the half-life of the rubidium isotope may be larger than the traditionally accepted value.

Explain how this would affect the ages obtained by this dating method.

(2)

If $t'_{1/2}$ is greater then λ will decrease at $\lambda = \frac{\ln 2}{t_{1/2}}$

Since the age $= \frac{\ln\left(\frac{N_r + N_s}{N_s}\right)}{\lambda}$ the age ~~Ns will Ns~~ will increase using greater half life.

ResultsPlus
Examiner Comments

This is another example of an explanation that is made clearer using relevant equations.

Paper Summary

Based on their performance on this paper, candidates should:

- check that quantitative answers represent sensible values and to go back over calculations when they do not.
- remember that physical quantities have a magnitude and a unit and both must be given in answers to numerical questions.
- learn standard descriptions of physical processes, such as atomic spectra, and be able to apply them with sufficient detail to specific situations, identifying the parts of the general explanation required to answer the particular question.
- note that whenever you are given the diameter of a circle or sphere, you will need to decide whether to use the radius in the following calculation.
- practice using graphs and reading the scale values on either side of the point of interest to ensure you are using the scale correctly.
- remember the final reciprocal in situations such as using the lens formula or adding resistors in parallel.
- remember that when substituting in an equation with a power term, eg x^2, don't suddenly miss off the index when substituting or forget it in the calculation.
- be sure to convert all values to the same SI units in questions with mixed quantities, eg do not mix cm and mm with the lens formula.
- understand that where you are asked to make a judgement or come to a conclusion by command words such as 'deduce whether', you must make a clear statement, including any values being compared.

Grade boundaries

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