2024 ASSESSMENT REPORT
PHY415115 PHYSICS 4

General Comments

Overall, the examination included a broad range of questions that required students to demonstrate knowledge of most of the course content. Candidates were given ample opportunity to accumulate marks across all four sections of the paper, and it was observed that few students scored very low numbers of marks.

Criterion 5 – Newtonian Physics

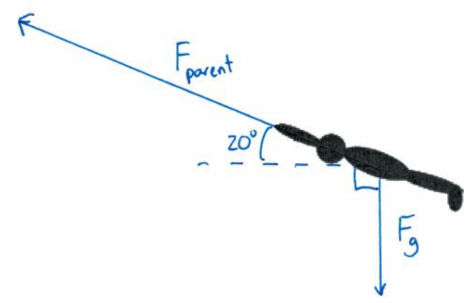
Question 1

General Comments

This question was done moderately well by a majority of candidates, although relatively few candidates secured full marks. In many cases, candidates who received very few marks for parts b) and c) were able to secure full or close-to-full marks for parts d) and e).

Question 1a)

Answer



Marking Notes

- 0.5 marks were deducted if forces weren't roughly to scale.
- 0.5 marks were deducted if the angle wasn't roughly to scale.
- 0.5 marks were deducted if net force or centripetal force were shown as forces (dashed lines OK).
- 1 mark was deducted for any force shown acting away from the parent (either horizontal or angled).

Marker's Comments

Surprisingly few candidates received full marks, mostly due to issues of scale. A large number of candidates showed a "centripetal" force acting oppositely to the force of the parent on the child.

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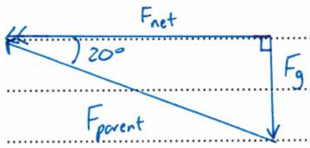
Question 1b)

Answer



$\sin 20° = F_g / F_{parent}$

$\therefore F_{parent} = F_g / \sin 20°$

$= 25 \times 9.81 / \sin 20°$

$= 717\ N$

Marking Notes

- 1 mark was awarded if a trigonometric relationship was recognised but incorrectly applied.

Marker's Comments

Many candidates confused the centripetal (net) force and the force of the parent on the child. Other common errors included using cos or tan instead of sin, attempting to use Pythagoras' Theorem with insufficient information, or attempting to use the formula for centripetal force (also with insufficient information). It is important to note that, although a vector triangle was not explicitly required by the question, the use of a triangle correlated strongly with success.

Question 1c)

Answer

$\tan 20° = F_g / F_{net}$ $\quad \therefore F_{net} = F_g / \tan 20°$

$= 25 \times 9.81 / \tan 20°$

$= 674\ N$ centrally

Marking Notes

- Full marks were awarded for correct use of Pythagoras' Theorem as an alternative approach.
- 0.5 marks were deducted if a correct direction was not included in the answer.

Marker's Comments

The use of a vector triangle in part b) correlated strongly with success in this part of the question.

Question 1d)

Answer

$F_{net} = \frac{mv^2}{r}$ $\quad \therefore v = \sqrt{F_{net} \times r / m}$

$= \sqrt{673.8 \times 1.3 / 25}$

$= 5.92\ ms^{-1}$

Marking Notes

- 0.5 marks were deducted if the force of the parent on the child was used instead of the net force.

Marker's Comments

This question was done well by a majority of candidates. Most were awarded full marks, although in many cases due to an allowance for a previous error carried forward.

Question 1e)

Answer

$$t = \frac{d}{v} = \frac{2\pi r}{v} = \frac{2 \times \pi \times 1.3}{5.919}$$

$$= 1.38\ s$$

Marker's Comments

This question was done well by a majority of candidates. A large proportion successfully used an alternative approach starting with the formula for centripetal force.

Question 2

General Comments

This question was done moderately well by a majority of candidates, although very few candidates secured full marks. In most cases, candidates failed to properly include the frictional force, with implications for parts b) and d).

Question 2a)

Answer

$$F_f = \frac{10}{100} \times mg = 0.1 \times 1.00 \times 9.81$$

$$= 0.981\ N$$

Marking Notes

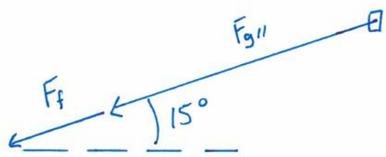
- 0.5 marks were awarded if the candidate calculated 10% of the parallel component of the weight.
- 0 marks were awarded if the candidate calculated 10% of the mass of the cart.

Marker's Comments

A surprisingly large number of candidates made one of the errors indicated above.

Question 2b)

Answer



$$F_{net} = F_{g//} + F_f$$

$$a = \frac{F_{net}}{m} = \frac{F_{g//} + F_f}{m} = \frac{mg\sin\theta + 0.981}{1.00}$$

$$= 1.00 \times 9.81 \times \sin 15^\circ + 0.981$$

$$= 3.52\ ms^{-2} \text{ down the ramp}$$

Marking Notes

- 1 mark was deducted for subtracting the frictional force rather than adding it.

Marker's Comments

This question was moderately well done. In most cases, a correct diagram led to a correct answer. Many students carried errors forward from part a).

Question 2c)

Answer

$2as = v^2 - u^2 \quad \therefore s = (v^2 - u^2)/2a$

$= (0^2 - 1.5^2)/(2 \times -3.52)$

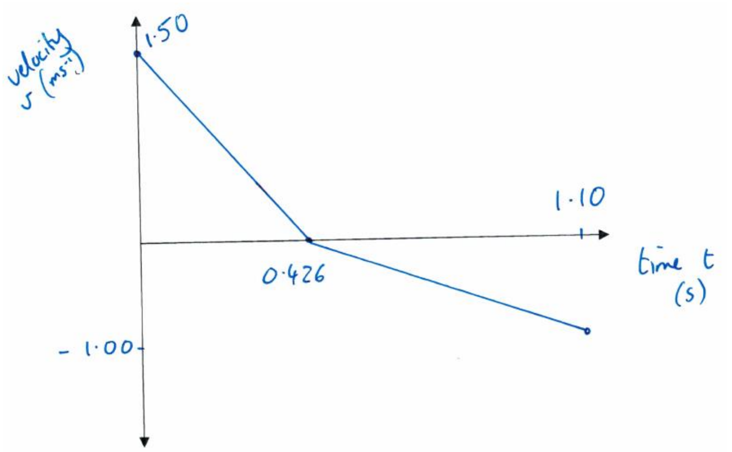
$= 0.320\,m$

Marker's Comments

This question was done well by a majority of candidates. An energy-based approach could work in theory but was not successfully done by any of the candidates who attempted it.

Question 2d)

Answer



Up ramp:

$u = 1.5\,ms^{-1}$

$v = 0\,ms^{-1}$

$t = (0 - 1.5)/(-3.52)$

$= 0.426\,s.$

Down ramp:

$a = g\sin\theta - 0.981$

$= 1.56\,ms^{-2}$

$u = 0\,ms^{-1}$

$s = 0.320\,m$

$s = \frac{1}{2}at^2$

$\therefore t = \sqrt{2s/a}$

$= \sqrt{\frac{2 \times 0.320}{1.56}}$

$= 0.641\,s$

$v = at$

$= 1.56 \times 0.641$

$= 1.00\,ms^{-1}$

Marking Notes

- A maximum of two marks were awarded if the candidate did not recognise that the acceleration for the downwards motion is different to the acceleration for the upwards motion.

Marker’s Comments

Very few candidates achieved full marks for the question. Common errors included only showing the upwards motion, making the downwards motion symmetrical with the upwards motion, ignoring downwards motion completely, and using curved lines on the graph.

Question 3

General Comments

This question was very well done overall, with most candidates securing close-to-full marks. Calculation errors were frequent but were minimally penalised in the cases where candidates had written out the values that were being input to the calculation.

Question 3a)

Answer

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

$$= \frac{6.67 \times 10^{-11} \times 2.79 \times 10^{30}}{(1.5 \times 10^{4})^2}$$

$$= 8.27 \times 10^{11} \text{ N kg}^{-1}$$

Marking Notes

- 0.5 marks were deducted if the diameter was used, as opposed to the radius.

Marker’s Comments

This question was done well by the majority of candidates. Common errors included failing to halve the diameter, failing to square the radius, and failing to convert kilometres to metres.

Question 3b)

Answer

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

$$= \sqrt{\frac{4 \times \pi^2 \times (9 \times 10^{10})^3}{6.67 \times 10^{-11} \times 2.79 \times 10^{30}}}$$

$$= 1.244 \times 10^{7} \text{ s}$$

$$\therefore T = \frac{1.244 \times 10^{7}}{24 \times 60 \times 60}$$

$$= 144 \text{ days}$$

Marking Notes

- 1 mark was deducted for using the pulsar radius from part a) instead of the orbital radius.

Marker’s Comments

This question was done well by the majority of candidates. Common errors included calculator errors, failing to correctly convert seconds to days, and using the pulsar radius instead of the orbital radius. Some candidates attempted to use the relationship between period squared and radius cubed, incorrectly interpreting the radius of the pulsar as a radius of orbit.

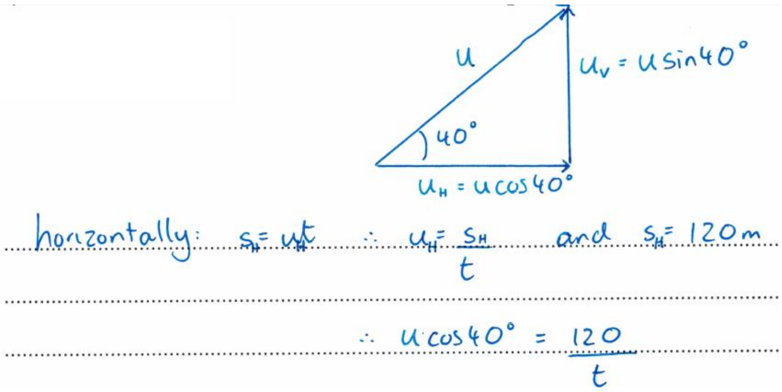
Question 4

General Comments

This question was well done by a good number of candidates but caused problems for an even larger number. In many cases, the derivations in part a) weren't well done, but the calculation in part b) was done correctly. The terminology "derive" appeared to have caused confusion for some candidates.

Question 4ai)

Answer

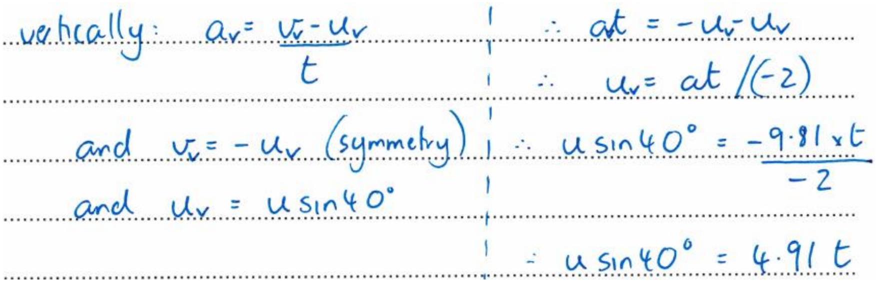


Marker's Comments

Candidates who achieved success on this question recognised that it required them to equate two formulae for the horizontal component of the initial velocity.

Question 4aii)

Answer



Marker's Comments

An alternative approach involved using $s = u_v t + \frac{1}{2}at^2$ for vertical motion, with $s = 0$ and $a = -9.81$.

Question 4b)

Answer

From (i) $t = 120/u\cos 40^\circ$

From (ii) $t = u\sin 40^\circ/4.91$

$\Downarrow$

$$\therefore \frac{120}{u\cos 40^\circ} = \frac{u\sin 40^\circ}{4.91}$$

$$\therefore u^2 = \frac{120 \times 4.91}{\cos 40^\circ \times \sin 40^\circ}$$

$$\therefore u = \sqrt{\frac{120 \times 4.91}{\cos 40^\circ \times \sin 40^\circ}}$$

$$= 34.6\ ms^{-1}$$

Marker’s Comments

There were a number of successful approaches to this question, including finding a value for time and substituting to find the velocity. Overall, this was done successfully by a large proportion of candidates, even if part a) was unsuccessful.

Question 5

General Comments

This question was very well done by a large majority of candidates.

Question 5a)

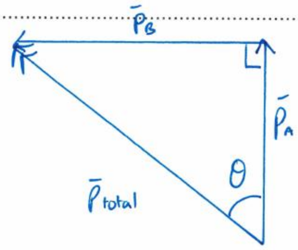
Answer

$\bar{p}_A = 65 \times 5$

$= 325\ kgms^{-1}$ N

$\bar{p}_B = 72 \times 5.5$

$= 396\ kgms^{-1}$ W



$p_{total} = \sqrt{p_A^2 + p_B^2}$

$= \sqrt{325^2 + 396^2}$

$= 512\ kgms^{-1}$

$\theta = \tan^{-1}(p_B/p_A)$

$= \tan^{-1}(396/325)$

$= 50.6^\circ$

$\therefore \bar{p}_{total} = 512\ kgms^{-1}$ N 50.6° W

Marking Notes

- Marks were awarded here for a direction calculation even if the calculation was performed in part b).

Marker’s Comments

Common errors included calculator error, simply adding momentum (rather than a vector addition), confusing east with west, reversing the final momentum vector, and inverting the tan ratio.

Question 5b)

Answer

$$\bar{v}_{tot} = \frac{\bar{p}_{tot}}{m_{tot}} \qquad \therefore v_{tot} = \frac{512.3}{65 + 72}$$

$$= 3.74\ ms^{-1}$$

$$\therefore \bar{v}_{tot} = 3.74\ ms^{-1}\ N\ 50.6°\ W$$

Marking Notes

- 0.5 marks deducted for not including direction with the velocity.

Marker’s Comments

This question was done well by the majority of candidates.

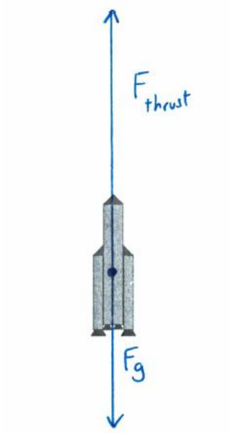
Question 6

General Comments

This question attracted a broad range of responses, although even those candidates who answered it poorly overall were able to secure some marks. The most common error, as might be expected, was that candidates completely ignored the weight of the rocket and treated the force of the rocket motors as the only force acting. In many cases, this was despite having correctly shown the weight force on the diagram in part a).

Question 6a)

Answer



Marking Notes

- F_{thrust} needed to be visibly larger than F_g. Many candidates usefully added a note to this effect.
- Drag or frictional forces were not required but were also not penalised.
- Some candidates included a normal force, which was not penalised if shown appropriately.

Marker’s Comments

The most commonly occurring error was the relative scale of the two forces.

Question 6b)

Answer

$$\bar{F}_{net} = m\bar{a} \qquad \therefore\ ma = F_{thrust} - F_g$$

$$\bar{F}_{net} = \bar{F}_{thrust} + \bar{F}_g \qquad \therefore\ F_{thrust} = ma + mg$$

$$= 7.8 \times 10^5 (2 + 9.81)$$

$$= 9.21 \times 10^6\ N$$

Marking Notes

- 0.5 marks were awarded if the weight force was not included in the calculation.
- 1 mark was awarded if the weight force was subtracted from (rather than added to) the net force.

Marker's Comments

A surprising number of candidates failed to include the weight force in their calculation at all.

Question 6c)

Answer

$$F_{thrust} = m(a + g)$$

$$\therefore\ m = \frac{F_{thrust}}{a + g} = \frac{9.212 \times 10^6}{30 + 9.81}$$

$$= 2.31 \times 10^5\ kg$$

Marking Notes

- 1 mark was awarded if the candidate ignored the weight force but correctly used the value of the force provided by the rocket motors from part b).
- 2 marks were awarded if the candidate subtracted (rather than added) the value of 9.81.

Marker's Comments

This part was well done by the candidates who successfully answered part b), and poorly done by candidates who did not successfully answer part b).

Criterion 6 – Electromagnetism

The Electromagnetism part of the Physics paper was a well-balanced section, giving the candidates sufficient time to answer all the questions. The questions covered the range of standards giving candidates plenty of opportunity to demonstrate their knowledge and skills.

Question 7

Question 7a)

Answer

$F_E = k_E q_1 q_2 / r^2$

$= 9\times10^{9} \times 3.2\times10^{-19} \times 1.6\times10^{-19} / (4\times10^{-10})^2$

$= 2.88 \times 10^{-9}$ N

Marker's Comments

This was generally well answered by most candidates. The most common mistakes included:

- using the field equation $E = \frac{kq}{r^2}$ and then using $F = Eq$ but making a mistake with the charges, often using single charge or double charge for both
- writing the correct equation but forgetting to square the radius
- using the charge of single electron instead of double for the calcium ion.

Question 7b)

Answer

$v = \frac{s}{t} = \frac{1.0}{2.275\times10^{-6}} = 4.40\times10^{5}\ ms^{-1}$

Marker's Comments

This question was well answered by most candidates. Candidate mistakes included:

- thinking that $\frac{1}{2.2\times10^{-6}} = 2.2\times10^{6}$
- using $E = \frac{V}{d}$, $V = \frac{E}{q}$ and then $E = \frac{1}{2}mv^2$, resulting in a lot of confusion, making the problem far more complicated than it needed to be.

Question 7c)

Answer

$E_K = E_P = Vq$

$= 2\times10^{4} \times 3.2\times10^{-19}$

$= 6.4\times10^{-15}$ J $\sim 6\times10^{-15}$ J

Marker's Comments

This question was well answered by most candidates. The most common error was using e as the charge, rather than 2e).

Question 7d)

Answer

$E_k = \frac{1}{2}mv^2 \quad \therefore m = 2 \times E_k / v^2$

$= 2 \times 6.4 \times 10^{-15} / (4.4 \times 10^5)^2$

$= 6.61 \times 10^{-26}$ kg.

Marker’s Comments

This question was well answered by most candidates. Most common mistake was forgetting to square the v or to keep the factor of 2.

Question 8

General Comments

Some candidates believed that they had to use the numbers provided in some way to determine their answers and as a result missed what the questions where actually asking.

Question 8a)

Answer

Alternating current in the coil creates a changing magnetic field in the vicinity of the coil.
The changing field induces eddy currents in the plate.
Lenz's Law says that the magnetic field produced by the eddy currents will oppose the coil's field.
⇒ the coil and plate repel each other.

Marker’s Comments

This question was well done by some candidates. Most common mistakes included:

- using Fw in their explanation
- discussing electrical charge
- many students incorrectly justified using the Right Hand Rule.

Question 8b)

Answer

The plate would fall slowly downwards (some velocity would be required to induce eddy currents).

Marker’s Comments

Most candidates got this correct. Most common mistakes included stating that the copper disc would fly away or fall off. Candidate errors were largely due to their misunderstanding of what they were being asked to describe.

Question 8c)

Answer

In a steel plate, induced magnetism would attract the plate strongly to the coil.

Marking Notes

- This question did not indicate whether it was a continuation of 8A or 8B, as a result the responses varied according to the candidate's choice. Most candidates attempted the question and provided a reasonable response.

Question 9

Question 9a)

Answer

$\Delta E_k = \Delta E_p$

$\therefore \frac{1}{2}mv^2 = Vq$

$\therefore v = \sqrt{\frac{2Vq}{m}} = \sqrt{\frac{2 \times 3 \times 10^3 \times 1.6 \times 10^{-19}}{9.11 \times 10^{-31}}}$

$= 3.25 \times 10^7 \ ms^{-1}$

Marker's Comments

This was generally well answered by most candidates. Many candidates did not include a statement like E_p=E_k to justify the next step in solving the problem. Mistakes included getting confused with E-field and Energy symbols.

Question 9b)

Answer

$E = \frac{V}{d} = \frac{2000}{0.05} = 4 \times 10^4 \ NC^{-1}$ up.

Marker's Comments

This question was well answered by most candidates. The most common mistake was not stating the direction of the E-field.

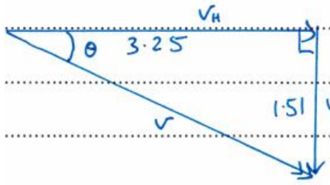
Question 9c)

Answer

$t = \frac{s_H}{u_H} = \frac{0.07}{3.246 \times 10^{7}} = 2.15 \times 10^{-9}$ s

$a_v = \frac{F_E}{m} = \frac{Eq}{m} = \frac{4 \times 10^{4} \times 1.6 \times 10^{-19}}{9.11 \times 10^{-31}} = 7.03 \times 10^{15}$ ms^{-2}

$V_v = at = 7.025 \times 10^{15} \times 2.15 \times 10^{-9} = 1.51 \times 10^{7}$ ms^{-1} down



$\theta = \tan^{-1}(1.510/3.246)$

$= 24.9°$ below horizontal

Marker's Comments

This question was generally well done by many candidates. Common mistakes included:

- making a vector triangle with displacement rather than velocity
- mistakes with scientific notation resulting in magnitude errors.

Question 9d)

Answer

$v = E/B$

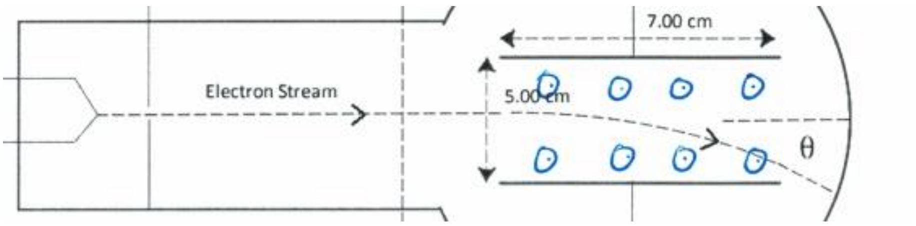
$\therefore B = \frac{E}{v} = \frac{4 \times 10^{4}}{3.246 \times 10^{7}} = 1.23 \times 10^{-3}$ T

Marker's Comments

This question was generally done well by candidates. The most common mistake was using a component of the velocity rather than the full vector.

Question 9e)

Answer



Marker's Comments

Poorly done by many candidates, opposite field indicated, due to forgetting that it is an electron.

Question 10

Question 10a)

Answer

$$F_B = IlB\sin\theta$$
$$= 5 \times (30 \times 0.05) \times 0.2 \times \sin 90^\circ$$
$$= 1.5\ N$$

Marker's Comments

This question was generally well answered by most candidates. The most common mistake was not multiplying 'L' by 30 because the wire rectangle consisted of 30 turns.

Question 10b)

Answer

Counter-clockwise.
B field lines are right → left. Current is as shown.
⇒ RHR says that F_B on AB is down.

Marker's Comments

This was answered well by most candidates. The most common mistake was stating that it would move clockwise as a result of using the RHR incorrectly.

Question 10c)

Answer

Gap is requred so that the current ceases flowing and then reveses, in order to maintain anti-clockwise motion.

Marker's Comments

This question was generally well answered by most candidates. The most common mistakes were:

- not explaining the continued aspect of the motion
- missing the fact that the current would always be in the same direction within the field so that the forces would also stay in the same direction.

Question 11

Question 11a)

Answer

$$v = \frac{s}{t} = \frac{2\pi r}{(1/50)} = \frac{2 \times \pi \times 0.01}{0.02}$$

$$= 3.14\ ms^{-1}$$

$$\sim 310\ cms^{-1}$$

Marker’s Comments

This question was well answered by most candidates. Most common mistakes included:

- using $F_B = qvB$
- not turning the frequency into a period (using 50 instead of 0.02).

Question 11b)

Answer

$$emf = vlB \sin\theta$$

$$\text{max } emf = 3.142 \times (30 \times 0.05) \times 0.2 \times \sin 90° \quad \left(\text{max. at } 90°\right)$$

$$= 0.943\ V$$

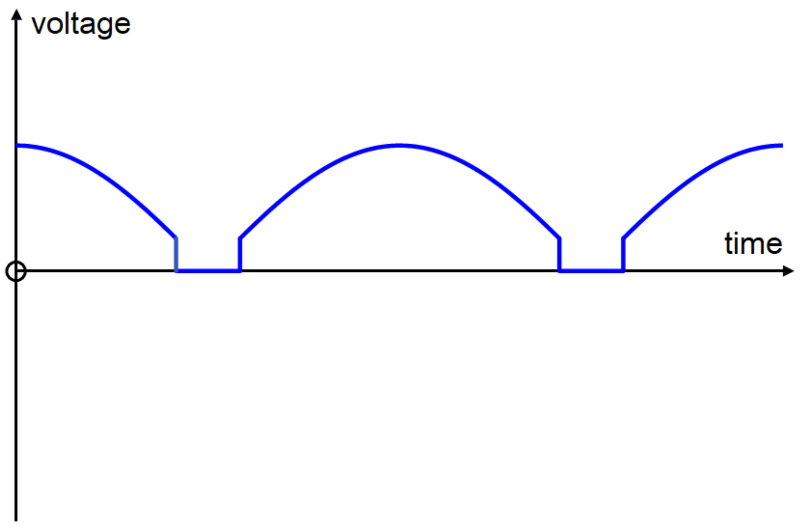
Marker’s Comments

Generally, well answered by many candidates. Mistakes included:

- using velocity in cm/s rather than m/s
- not multiplying the length by 30 (30 coils)
- using the 310cm/s instead of the answer that they actually calculated from 1a).

Question 11c)

Answer



Marker's Comments

This question was poorly done by a lot of candidates. There were lots of errors, including:

- drawing a full sine wave (+ve / 0 / -ve)
- drawing a horizontal line at 0.943V
- drawing a line on a negative slope
- drawing square waves
- drawing triangular waves.

Given that the question incorrectly referred to Figure 11 for the starting position of the coil (as opposed to Figure 10), the starting value for the graph was ignored in marking.

Question 11d)

Answer

$$I = V/R$$
$$= 0.943/20$$
$$= 4.715 \times 10^{-2}\ A$$

$$F_B = I l B \sin\theta$$
$$= 4.715 \times 10^{-2} \times (30 \times 0.05) \times 0.2$$
$$= 0.0141\ N$$

Marker's Comments

Generally done very well by most candidates. The most common problem was with error carried forward from 11b).

Question 12

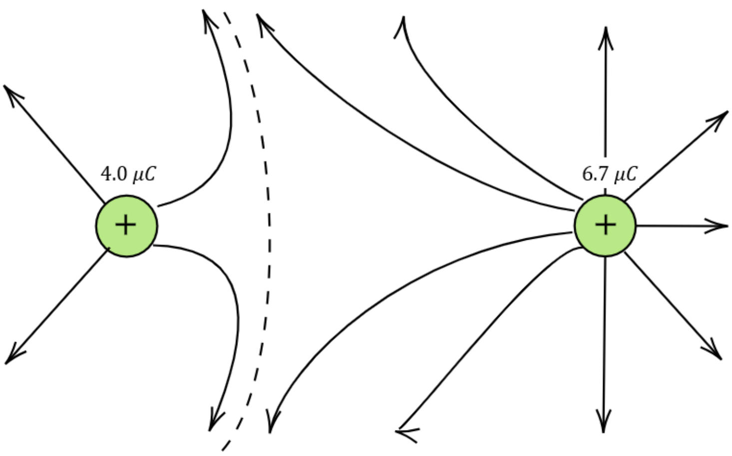
Although there were conflicting values in the question, this had little to no evident impact on candidates. The majority of candidates used the correct values indicated in the diagram rather than the incorrect value from the text. Some candidates removed the 10cm value from the text and wrote 7cm above it, as per the instructions given by the exam invigilators.

A very small number of candidates used 10cm for all 3 sides or used 7cm, 10cm, 7cm. Of those that did, their answers were correct.

Candidate responses were marked according to the numbers they used.

Question 12a)

Answer



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Marker's Comments

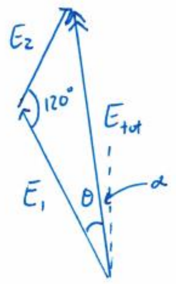
Candidate responses varied greatly. A common response was treating the charges as wires where the current was going in or out of the page.

For those that drew point charge field diagram, common mistakes included:

- incorrect density of field lines
- shape of the field lines
- direction of the field lines
- drawing a symmetrical diagram instead of asymmetrical as one charge was bigger than the other.

Question 12b)

Answer



$$\frac{\sin\theta}{7.347} = \frac{\sin 120°}{17.2}$$

$$\therefore \theta = \sin^{-1}\left(\frac{7.347 \times \sin 120°}{17.2}\right)$$

$$= 21.7°$$

$$\therefore \alpha = 30° - 21.7°$$

$$= 8.3°$$

$$E_1 = \frac{k_E q_1}{r^2} = \frac{9\times10^9 \times 6.7\times10^{-6}}{0.07^2} = 1.231 \times 10^7\ NC^{-1}$$

$$E_2 = \frac{k_E q_2}{r^2} = \frac{9\times10^9 \times 4 \times 10^{-6}}{0.07^2} = 7.347 \times 10^7\ NC^{-1}$$

$$E = \sqrt{12.31^2 + 7.347^2 - 2\times 12.31 \times 7.347 \times \cos 120°} \times 10^6$$

$$= 1.72 \times 10^7\ NC^{-1}$$

$\therefore E = 1.72 \times 10^7\ NC^{-1}$ up and 8.3° left of vertical

Marker's Comments

This question was done well by some candidates. The most common mistakes included:

- not drawing a vector diagram to determine field strengths and direction
- treating the problem as a right-angle instead of having an angle of 1200 between E1 and E2
- drawing the vector diagram incorrectly. (e.g., drawing it so that ET was right of the vertical, or even upside down)
- commonly forgetting to find the angle for the direction.

Question 12c)

Answer

$$F_E = Eq$$

$$= 1.72\times10^7 \times 2\times10^{-8}$$

$$= 0.344\ N$$

Marker's Comments

This was generally done well by most candidates. Errors carried forward was common as candidate responses from 12b) was required to answer 12c). Some candidates misread the question and attempted to find E instead.

Criterion 7 – Waves

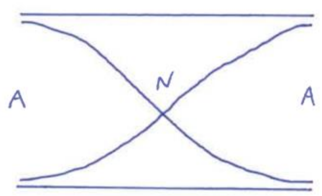
Question 13

Whilst completed well in general, candidates are reminded to attempt to represent sinusoidal shape when drawing wave patterns.

Question 13a)

Answer

A standing wave in the pipe causes resonance, which amplifies the sound. The standing wave is produced by interference of the wave with its own reflections from the ends of the pipe



A: antinode
maximum amplitude
constructive interference

N: node
minimum amplitude
destructive interference

Marking Notes

- 1 mark was awarded for the sketch portion.
- 2 marks total for the explanation, with the general approach of:
  - 1 mark for resonance
  - 1 mark for standing wave
  - 1 mark for reflection
  - 0.5 for constructive and destructive interference.

Marker's Comments

Supporting sketches were generally good. Candidates who mentioned resonance, reflection and standing waves did best.

Question 13b)

Answer

$L = \lambda/2 = v/2f \quad (\lambda = v/f)$

$= \frac{343}{2 \times 40}$

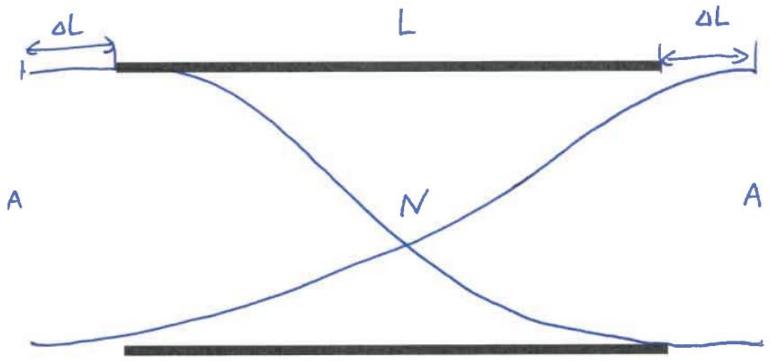
$= 4.29\ m.$

Marker's Comments

Very well done by the majority.

Question 13c)

Answer



Marking Notes

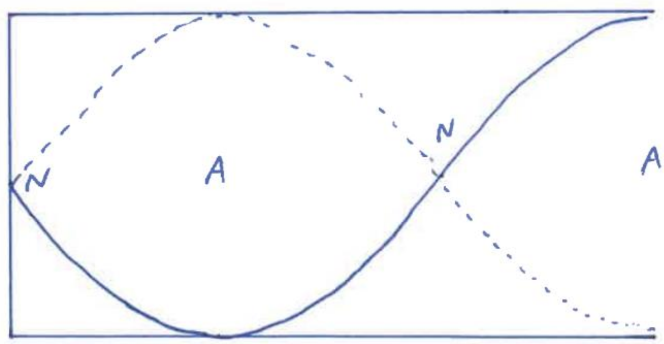
- 0.5 was awarded for candidates who represented the correct wave form with no end-correction adjustments.

Marker's Comments

Generally well done, although a small portion of candidates did not show the error correction, only placed it on one side, or placed the antinodes inside rather than outside the openings to the pipe.

Question 13d)

Answer



Marking Notes

- 0.5 was awarded to candidates who drew the first overtone in the open-open pipe.
- 1 was awarded to candidates who drew the first harmonic in an open-closed pipe.

Marker's Comments

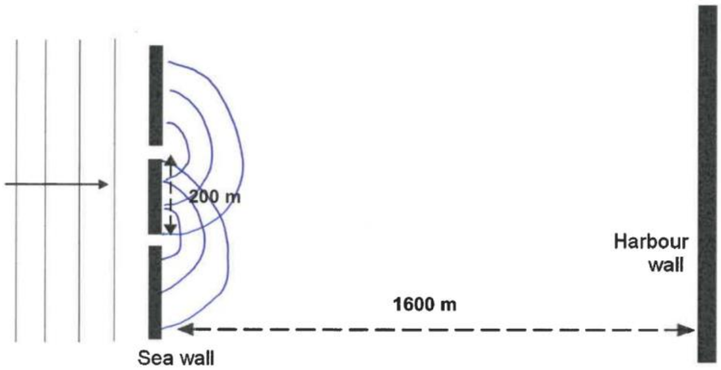
Generally well done, with occasional confusion around correct overtones or using the wrong type of pipe.

Question 14

Candidates found this to be one of the more challenging questions in this criterion. Wider applications of Young's Double Slit principles (e.g. two-source waves such as this, two speakers at a concert, two telescope receivers) should be approached in much the same way as conventional monochromatic Young's Double Slit setups.

Question 14a)

Answer



Marking Notes

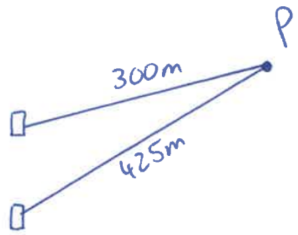
- 1 mark for concentric circles.
- 1 mark for matching wavelength λ before and after sea wall.

Marker's Comments

The circular shape of wavefronts, emerging from an application of Huygen's principle, were generally well-represented. However, many candidates did not attempt to maintain λ across the sea wall. Some candidates noted that λ was maintained with a note, which is also satisfactory.

Question 14b)

Answer



PD = 425 - 300

= 125 m

= 2·5 × λ (λ = 50m) ⟹ destructive interference : node.

The boat would experience calm conditions.

Marking Notes

- 1 for the sketch portion.
- 1 for a suitable calculation.
- 1 for correct application of the calculated result.

Marker's Comments

It was common for candidates to demonstrate a partial understanding and receive partial marks. Common errors and misconceptions included:

- incorrect path difference methods (e.g., using trigonometry, Pythagoras, division) rather than simply subtracting the path lengths
- no path difference calculations or mention

- associating a $\left(n - \frac{1}{2}\right)\lambda$ path difference with adding a node and an antinode together, rather than two perfectly out-of-phase wave paths.

Question 14c)

Answer

$W = \frac{\lambda x}{d} = \frac{50 \times 1600}{200}$

$= 400m$ separation of antinodes

Marker's Comments

Generally well done.

Question 14d)

Answer

The formula used is only valid when $x >> d$.
In this case $x > d$ but not significantly so.
The approximation will be reasonable for the first antinodal lines.

Marker's Comments

Candidates who demonstrated their understanding of the derivation or limitations of $W = \frac{\lambda x}{d}$ did the best, such as when referring to the small angle approximation or the need for $x \gg d$. When candidates took other directions, but were clear and accurate, they were also rewarded. Candidates who gesticulated non-specifically in the direction of 'external factors' were not rewarded.

Question 15

This question was completed to a high standard in a large majority of cases.

Question 15a)

Answer

$n_i \sin\theta_i = n_r \sin\theta_r$

$\therefore 1 . \sin 62° = 1.33 \sin\alpha$

$\therefore \alpha = \sin^{-1}\left(\frac{\sin 62°}{1.33}\right)$

$= 41.6°$

$\theta = 90 - \alpha$

$= 90 - 41.6$

$= 48.4°$

Marking Notes

- Only 2 out of 3 marks were awarded where candidates failed to correctly account for the water-air interface being at right-angles to the glass/water interface.

Marker's Comments

The majority of candidates did well, with only a small minority omitting the $90 - \theta$ or applying $90 - \theta$ in the wrong place.

Question 15b)

Answer

critical angle: $\theta_c = \sin^{-1}(1/1.33)$

$= 48.7°$

Yes. Light will emerge because $\theta_i < \theta_c$.

Marker's Comments

Generally well done, with two main approaches, both of which could receive full marks. One approach was to evaluate the critical angle and show that it was not met, hence leading to refraction rather than total internal reflection. The other approach was to proceed as if refraction could occur, and show that θ_r was less than $90°$.

Question 15c)

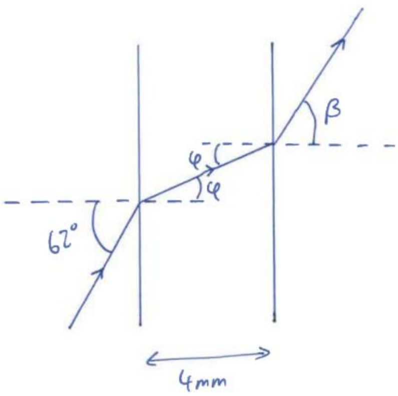
Answer

$\varphi = \sin^{-1}\left(\frac{\sin 62°}{1.58}\right)$

$= 33.97°$

$\beta = \sin^{-1}\left(\frac{1.58 \times \sin(33.97°)}{1.33}\right)$

$= 41.6°$ This is the same angle as in part a), when glass was ignored.



Marking Notes

- 1 mark awarded for the first refraction.
- 1 mark awarded for the second refraction.
- 1 mark awarded for the correct interpretation, that the angle of emergence into the water was the same in either case.
- 1.5 marks total for candidates who found the first angle of refraction, and calculated the vertical displacement, but no further working or reasoning.

Marker's Comments

To receive full marks, candidates need to show that the angle with which the light emerges into the water was the same in either case. A small number of candidates were able to show this by demonstrating that the 'middle' refraction term cancelled out by combining multiple Snell's law refractions into the original one.

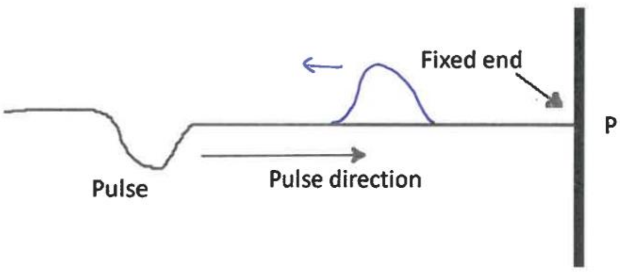
Question 16

General Comments

- This question was answered very well by the candidates with many candidates gaining full marks or close to full marks.
- More care could have been taken by students drawing their sketch diagrams and some candidates did lose a small amount of half marks because of this.

Question 16a)

Answer



Marking Notes

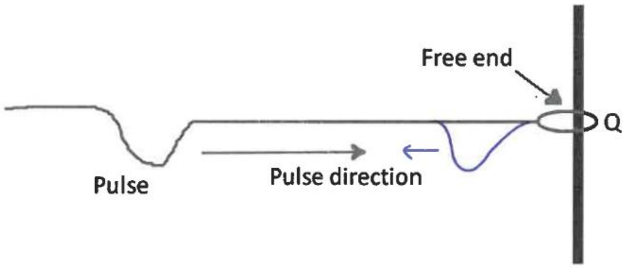
- 1 mark for correct diagram with the reflected pulse with correct orientation.
- Loss of 0.5 mark if the reflected pulse had noticeably higher amplitude or the asymmetry (if shown) was wildly incorrect.

Marker's Comments

This question was answered very well. Generally speaking, if the reflected pulse was shown with the incorrect orientation, then Question 16b was also incorrect.

Question 16b)

Answer



Marking Notes

- 1 mark for correct diagram with the reflected pulse with the correct orientation.
- Loss of 0.5 mark if the reflected pulse had noticeably higher amplitude or the asymmetry (if shown) was wildly correct.

Marker's Comments

This question was answered very well. While obvious to the markers, it would have been helpful for students to draw an arrow showing the direction of the pulse.

Question 16c)

Answer

$$v = \sqrt{\frac{T}{\mu}} = \sqrt{\frac{17}{0.017}} = 31.6\ ms^{-1}$$

Marking Notes

- 1 mark was deducted for failing to do the required unit conversion, so the mass was converted into kilograms.

Marker's Comments

This question was largely well answered but the most common error was for candidates to forget to convert from $g\ m^{-1}$ into $kg\ m^{-1}$. Some candidates thought that T in the formula meant period instead of tension and were unable to proceed further.

Question 16d)

Answer

It will slow down due to the heavier string (μ increasing implies v will decrease).

Marking Notes

- 1 mark for correctly stating that the pulse will slow down.

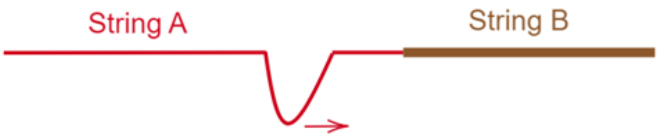
Marker's Comments

The description ("slower") required in the answer was almost universally provided, meaning that a vast majority of candidates gained full marks. However, many candidates were fortunate that this was a 'describe' rather than 'explain' or 'justify' question, as the candidates that went on to explain their reasoning often did not consider the heavier mass per unit length in their thinking.

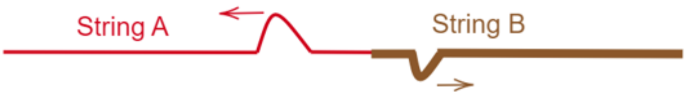
Question 16e)

Answer

Before:



After:



Marking Notes

- For full marks candidates needed to show on the diagram the different speeds of the pulses, the correct orientation and some attempt at indicating a change in amplitude of at least one of the pulses after interaction with the boundary.

Marker's Comments

While many candidates gained most of the marks, few of them gained full marks. Many candidates realised that there would be changes in amplitude for the reflected and transmitted pulses but did not clearly show that the transmitted pulse would be travelling at a reduced speed (and therefore closer to the boundary of String A and String B) than the reflected pulse. Some candidates confused the orientation of the pulses, although there was an opportunity for some very limited error carried forward from how 16a) and 16b) were answered. While not specifically looked for in candidates' answers, it is pleasing to note that many candidates realised that the pulse in String B will have a shorter wavelength.

Question 17

General Comments

- This question proved more challenging than Question 16. Certain parts were very well answered with other parts being very poorly answered.

Question 17a)

Answer

S waves are transverse (they don't travel into the liquid outer core).

Marking Notes

- This obtained either 1 mark or 0 marks.

Marker's Comments

This question proved very easy for candidates that had read the description of the question with less than 5% of candidates not getting the full mark.

Question 17b)

Answer

A liquid cannot provide the required restoring force (it must be perpendicular to the wave's motion).

Marking Notes

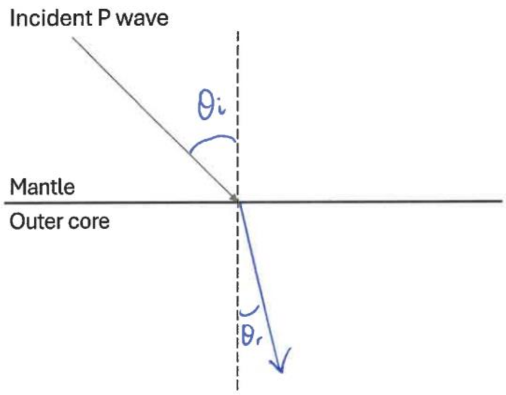
- 1 mark if the idea of a restoring force is mentioned, with a partial mark if the restoring force idea was implicit in the candidate's answer.

Marker's Comments

It was clear in answers to this question that candidates were almost universally unaware of the idea that transverse matter waves cannot be transmitted through a liquid (unlike electromagnetic waves). The most common incorrect explanation was that liquids are incompressible. Only 3% of candidates were able to answer this question correctly.

Question 17c)

Answer



Marking Notes

- Either 1 mark or 0 marks was obtained by each candidate.

Marker's Comments

This question was done very well. The most obvious error was that candidates drew the angle of refraction as greater than the angle of incidence. A few candidates did not show a sufficient difference in angle for their intention to be obvious in their answer.

Question 17d)

Answer

$\theta_r < \theta_i$ which implies the wave must slow down when it crosses the boundary.

Marking Notes

- This was marked as either 1 mark or 0 marks.

Marker's Comments

This question was done well with an opportunity for the error in 17c) to be carried forward. Many candidates gave additional reasoning which was not required and was often incorrect but did not lose them marks as they correctly deduced the answer from 17c). The most common incorrect reason was due to increasing density which was wrong and may be because candidates are confusing the idea of optical density with light waves (which slows them down), whereas sound or earthquake waves travel faster in a denser medium (particles are closer together). Liquids are less dense than solids.

Question 17e)

Answer

Gradual increase in density causes corresponding gradual increase in wave speed. This causes waves to smoothly curve away from the normal to the line of equal wave speed. Since these “equi-speed” (contour-like) lines are curved due to the spherical geometry of the mantle or outer core, the wave direction will begin to smoothly curve back towards boundary when the wave direction becomes tangent to this equi-speed line.

Marking Notes

- The ideas of gradually increasing density causes increasing wave speed and that the direction of the wave will gradually curve away from the region of increasing wave speed (or similar ideas) were required for full marks.

Marker’s Comments

Many candidates found this part of the question to be particularly challenging and only a few achieved full marks, although many achieved at least 1 mark. The most common misconceptions were that increasing density causes a decrease in wave speed and that if a normal is drawn from ‘equi-speed’ lines, that the wave would be bending in towards the normal rather than away from the normal. When candidates talked about “refractive index” instead of “wave speed” then they also could get confused thinking that a denser medium would mean a higher relative refractive index for P waves. This is true for light but not sound (which is the other way around). In fact, it is best to use wave speed to think about sound/earthquake waves and refractive index to think about visible light and other electromagnetic waves.

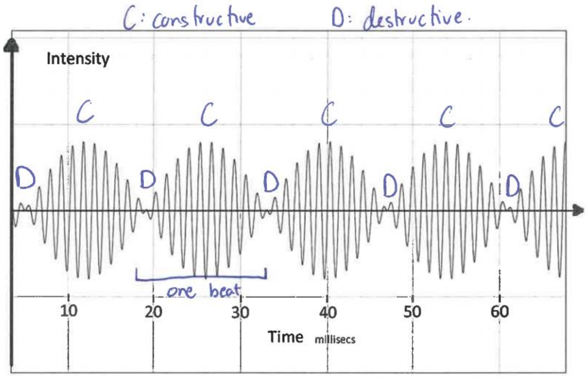
Question 18

General Comments

- This question was very well answered, although a few candidates who clearly demonstrated elsewhere in the question that they understood this topic very well missed labelling the regions of constructive and destructive interference on the diagram and thus the 2 marks associated with that simple process.

Question 18a)

Answer



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Marking Notes

- 1 mark for labelling constructive interference and 1 mark for destructive interference with a loss of 0.5 mark if the regions appeared to overlap because of messy labelling.

Marker's Comments

This was almost universally done correctly by candidates. Only a small minority incorrectly thought that the wave form above the horizontal axis indicated constructive interference, with the wave form below indicating destructive interference.

Question 18b)

Answer

See the "one beat" annotation on the diagram to the answer to 18a).

Marking Notes

- 1 mark for a beat correctly identified, with a loss of ½ mark if the boundary was too imprecise.

Marker's Comments

This was done very well, except for candidates that chose to skip this part (and often the next part) of the question. A few candidates incorrectly identified a beat as being from peak to very close adjacent peak of the high frequency sinusoidal curve instead of being from the high point of the amplitude envelope of one envelope to the adjacent envelope.

Question 18c)

Answer

Time: 5 msec → 61 msec includes four beats.

∴ time per beat = (61 − 5)/4 = 14ms

∴ Frequency = $1/(14 \times 10^{-3})$ = 71.4 Hz

Marking Notes

- Partial marks were awarded if the beat identified in 18b) was measured wildly incorrectly, if the milliseconds were not converted to seconds, or the period rather than frequency was stated.

Marker's Comments

While many candidates achieved full marks, the most common errors were due to forgetting to convert the time to seconds or not applying the well known $f = 1/T$ correctly. The best answers measured the time for several beats and then divided by the number of beats to minimise measurement errors. There was an opportunity for error carried forward if candidates incorrectly identified the beat in 18b).

Question 18d)

Answer

910 ± 71.4 Hz ⟹ 981 Hz or 839 Hz

Marking Notes

- Candidates who only gave one possible frequency gained only 1 mark.

Marker's Comments

This question was done superbly well with almost every candidate giving at least one possible frequency and the vast majority identifying both possible frequencies. The rare incorrect responses were due to applying wave formulae entirely unrelated to the beat frequency formula $f_{beat} = |f_1 - f_2|$.

Criterion 8 – Twentieth Century

Question 19

General Comments

Many candidates struggled with the proportional reasoning required in 19b, otherwise this question was done well. Candidates should be reminded to carry forward "show that' values.

Question 19a)

Answer

$${}^{63}_{28}Ni \longrightarrow {}^{63}_{29}Cu + {}^{0}_{-1}\beta + \bar{\nu}$$

Marking Notes

- 0.5 mark for the mother nucleus.
- 0.5 mark for the daughter nucleus.
- 0.5 mark for beta (include charge and mass).
- 0.5 mark for the antineutrino.
- 0.5 marks were deducted for small errors.

Marker's Comments

- Many candidates forgot to include an antineutrino or used incorrect notation for it.

Question 19b)

Answer

In one second: $E = P$

$E = 100 \times 10^{-6}$ J

For one decay:

$E = 50 \times 10^{3}$ eV

$= 50 \times 10^{3} \times 1.6 \times 10^{-19}$

$= 8 \times 10^{-15}$ J

decays needed in one second:

$= \dfrac{100 \times 10^{-6} \text{ (J)}}{8 \times 10^{-15} \text{ (J/decay)}}$

$= 1.25 \times 10^{10}$ (decays)

$\simeq 1 \times 10^{10}$ Bq.

Marking Notes

- 1 mark for calculating the energy per beta particle.
- 1 mark for calculating the activity.

Marker's Comments

Very few candidates were awarded half marks. It was either correct, or there was little evidence of understanding.

Question 19c)

Answer

$A = \lambda N$

$\therefore N = A/\lambda$

$= \dfrac{1.25 \times 10^{10}}{(0.693/(101.2 \times 365 \times 24 \times 60 \times 60))}$

$= 5.757 \times 10^{19}$

$m = \dfrac{N \times M}{N_A}$

$= \dfrac{5.757 \times 10^{19} \times 63}{6.02 \times 10^{23}}$

$= 6.02\,mg$

Marking Notes

- 1 mark for calculating the decay constant.
- 1 mark for calculating the number of atoms.
- 1 mark for calculating the mass.
- 0.5 a mark deducted for using the approximate value (1x1010) rather than the value calculated in part b).

Marker's Comments

Make sure that the decay constant aligns with the unit of time.

Question 19d)

Answer

$m = m_o e^{-\lambda t}$

$= 6.025 \times 10^{-3} \times e^{\frac{-0.693}{101.2} \times 70}$

$= 3.73\,mg$

Marking Notes

- 0.5 marks deducted for errors.

Marker's Comments

Make sure that the decay constant and time use the same units of time. Some errors were made when converting between years and seconds.

Question 19e)

Answer

The daughter isotope has a stable nuclear configuration.

Marking Notes

- Either it is stable (0.5) and no excess energy is released (0.5) OR
- It is metastable (0.5) and will undergo another decay to release excess energy (0.5).

Marker's Comments

This question could be answered in two different ways depending on how it was interpreted and either answer was accepted.

Question 20

General Comments

This question was done very poorly. Candidates struggled to calculate the frequency in part a) and graphing was done poorly, even with correct values. Many candidates were unable to see the relationship between the values on the graph and the questions

Question 20a)

Answer

Wavelength (nm)	Frequency (Hz)	Stopping voltage (V)
546	5.49×10^{14}	0.13
436	6.88×10^{14}	0.71
405	7.41×10^{14}	0.90

Marking Notes

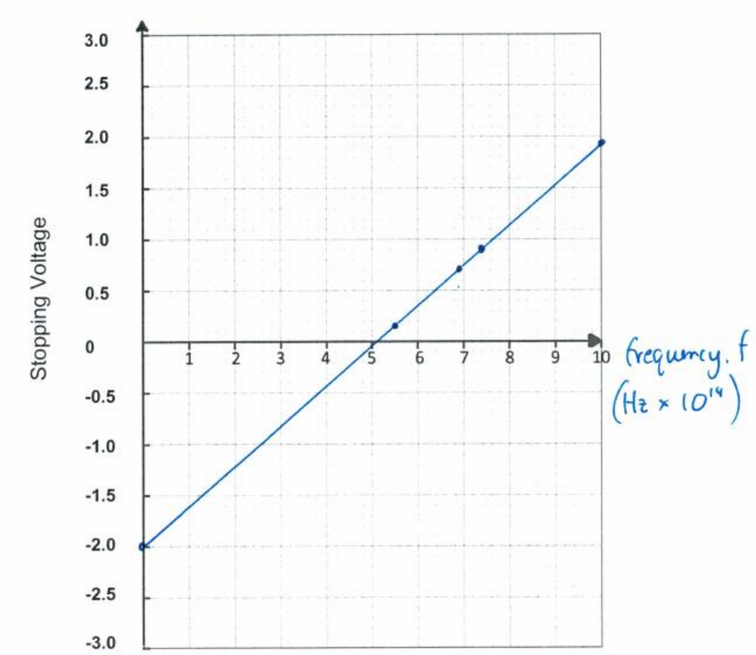
- No partial marks awarded.

Marker's Comments

There was a lot of variation in the answers provided. Several other equations were used.

Question 20b)

Answer



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Marking Notes

- 1 mark for points.
- 0.5 mark for linear relationship.
- 0.5 mark for labelling x axis.

Marker's Comments

Error carried forward from part a) was awarded. Given that the scale was provided it was expected that points were graphed accurately. Candidates should use a ruler when marking linear relationships.

Question 20c)

Answer

Frequency determines the energy of the incident photons ($E = hf$) which in turn determines the maximum kinetic energy of the photo electrons. Stopping voltage is the electric potential energy required to 'stop' the photoelectrons.

Marking Notes

- 0.5 the higher the frequency of the incident photon.
- 0.5 the higher the Ek of the photo electron.
- 0.5 voltage is required to stop the photoelectron.
- 0.5 voltage increases as f (and hence Ek) increases.

Marker's Comments

No marks were awarded for stating the relationship between f and V.

Question 20d)

Answer

i. Planck's Constant in electron-volt form.

h = gradient of graph $= \frac{1.95 - (-2.0)}{10} = 3.95 \times 10^{-15}$ eVs.

$(0, -2.0)$ and $(10, 1.95)$

ii. The work function.

W_0 = y-intercept

$= 2.0$ eV

iii. The cut-off frequency of caesium.

f_0 = x-intercept

$= 5.1 \times 10^{14}$ Hz

Marking Notes

- Part marks were awarded in part i. for stating that the gradient gave Plank's Constant.

Marker's Comments

No marks were awarded if candidates didn't use the experimental data. Part marks were awarded for parts ii. and iii. if the experimental value for Planck's constant was used in a calculation.

Question 21

General Comments

Candidates were penalised for significant figures in Question 21. There were numerous calculation errors. Candidates should use any extra exam time to double check their calculations.

Question 21a)

Answer

Reactants: $(26 \times m_p) + (26 \times m_e) + (30 \times m_n)$

$= (26 \times 1.007276) + (26 \times 0.000549) + (30 \times 1.008665)$

$= 56.46340$ u

− product: 55.9349375 u

$\Delta m = 0.5284625$ u

Marking Notes

- 0.5 marks were deducted for small errors such as missing units, rounding errors, etc.
- 0.5 marks were deducted for significant figures. 9 were given in the question so answer to 9 significant figures.
- 1 mark was deducted for failing to include the mass of the electrons.
- 0.5 marks were deducted for failing to realise that there were 30 neutrons.

Marker's Comments

There were many small calculation errors and rounding errors in this question.

Question 21b)

Answer

$\frac{\Delta m}{56} \times 931 \text{ MeV} = 8.79 \text{ MeV}$

Marking Notes

- 0.5 mark for AMU → MeV.
- 0.5 mark for binding energy per nucleon.

Marker's Comments

Make sure that questions are read carefully. Many candidates only completed half this question by either calculating the total binding energy or the amu/nucleon.

Question 21c)

Answer

Beyond iron, the binding energy per nucleon of the products is less than that of the reactants, therefore energy is consumed in the reaction.
If energy is consumed then the reaction cannot be sustained for long.

Marking Notes

- 1 mark for stating that beyond Fe the nuclei have lower binding energy per nucleon.
- 1 mark for stating that fusing heavier nuclei will require net energy loss and therefore cannot be sustained.

Marker's Comments

Read questions carefully. Many candidates discussed Fe rather than elements after Fe.

Question 22

General Comments

This question was generally done well except for small calculation and rounding errors.

Question 22a)

Answer

$$E = hf = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{633 \times 10^{-9}}$$

$$= 3.14 \times 10^{-19}\ J$$

Marking Notes

- 0.5 marks were deducted for small errors such as missing units, rounding errors, etc.

Marker's Comments

An answer in eV or J was accepted.

Question 22b)

Answer

In one second, $E = 3 \times 10^{-3}\ J$

$\therefore$ number of photons $= \dfrac{3 \times 10^{-3}\ (J)}{3.142 \times 10^{-19}\ (J/photon)} = 9.55 \times 10^{15}$ photons

Marking Notes

- 0.5marks were deducted for small errors such as missing units, rounding errors, etc.

Marker's Comments

- A few candidates mistakenly divided the joules per photon by the total energy.
- A few candidates mistook mW for MW.

Question 22c)

Answer

$$p = \frac{h}{\lambda} = \frac{6.63\times10^{-34}}{633\times10^{-9}} = 1.05\times10^{-27}\ \text{kgms}^{-1}$$

Marking Notes

- 0.5 marks were deducted for small errors such as missing units, rounding errors etc.

Marker's Comments

This question was done well by most candidates.

Question 22d)

Answer

$$F = \frac{\Delta p}{t} = \frac{1.047\times10^{-27}\times 9.55\times10^{15}}{1}$$

$$= 1.00\times10^{-11}\ \text{N}$$

Marking Notes

- 0.5 marks were deducted for small errors such as missing units, rounding errors, etc.
- Only 0.5 mark was awarded for calculating the force of one photon.

Marker's Comments

Many candidates forgot to take in account the number of photons hitting the wall.

Question 23

General Comments

Generally done well.

Question 23a)

Answer

$$\Delta E = 2.2\text{eV} = \frac{hc}{\lambda} \qquad \therefore \lambda = \frac{hc}{\Delta E} = \frac{4.14\times10^{-15}\times 3\times10^{8}}{2.2}$$

$$= 5.645\times10^{-9}$$

$$\simeq 560\ \text{nm}$$

Marking Notes

- 1 mark for 4.2 – 2.0 = 2.4eV.
- 1 mark for calculating the wavelength.

Marker's Comments

Completed accurately by most candidates.

Question 23b)

Answer

4.2eV is required at minimum, so that oxygen's electron can reach the 4.2eV level.

$E_k = 4.2 \times 1.6 \times 10^{-19}$

$= 6.72 \times 10^{-19}$ J

Marking Notes

- 1/2 mark for converting 4.2eV to J.
- 1/2 mark for calculating the wavelength.
- 1 mark for justification.

Marker's Comments

Many candidates answered that 2.2eV was required to excite an electron from the 2.0eV to 4.2eV and then drop back again, emitting green light. Remember that excitation is (mostly) from the ground state and doesn't happen in steps. Steps occur downwards only for the purpose of this course. An answer of 2.2eV was accepted if candidates stated that an excited electron was further excited and then dropped back down.

Question 23c)

Answer

$\Delta E = 1.6\text{eV}$ $\quad \therefore \lambda = (4.14 \times 10^{-15} \times 3 \times 10^{8})/1.6$

$= \dfrac{hc}{\lambda}$ $\quad = 776 \times 10^{-9}$ m

Beyond the visible spectrum: near infrared

Marking Notes

- 0.5 mark for 10.7eV – 9.1eV.
- 0.5 mark for calculating wavelength.
- 1 mark for identifying the part of the spectrum.

Marker's Comments

Many candidates were not able to identify the part of the spectrum. Many stated it was red visible light which was not awarded any marks. 700nm is the upper limit of red light.

Question 24

General Comments

This question was generally done well. Most marks were lost due to candidates failing to acknowledge that momentum is a vector.

Question 24a)

Answer

$$p = \frac{h}{\lambda} = \frac{6.63 \times 10^{-34}}{2.48 \times 10^{-11}} = 2.67 \times 10^{-23} \text{ kgms}^{-1} \text{ East.}$$

Marking Notes

- Half a mark was deducted for not including units of direction.
- Half marks were deducted for using 4.14×10^{-15} and quoting kgms^{-1} as the units.

Marker's Comments

- Many candidates forgot to include the direction.
- Some candidates forgot units.
- Remember that momentum is a vector!

Question 24b)

Answer

$$p = \frac{h}{\lambda} = \frac{6.63 \times 10^{-34}}{2.97 \times 10^{-11}} = 2.23 \times 10^{-23} \text{ kgms}^{-1} \text{ West}$$

Marking Notes

- Half a mark was deducted for not including units of direction.
- Half marks were deducted for using 4.14×10^{-15} and quoting kgms^{-1} as the units.

Marker's Comments

- Many candidates forgot to include the direction.
- Some candidates forgot units.
- Remember that momentum is a vector!

Question 24c)

Answer

$$\Delta p = 2.673 \times 10^{-23} - (-2.232 \times 10^{-23})$$

$$= 4.905 \times 10^{-23} \text{ kgms}^{-1}$$

$$\Delta v = \frac{\Delta p}{m} = \frac{4.905 \times 10^{-23}}{9.11 \times 10^{-31}}$$

$$= 5.38 \times 10^{7} \text{ ms}^{-1}$$

Marking Notes

- 1 mark for calculating the change in p.
- 1 mark for v = p/m.

Marker's Comments

- Most candidates treated both the incident and final momentum of the photon as being positive and therefore got the wrong answer.
- Many candidates calculated the recoil speed of the electron by using the momentum of the scattered photon.