

2022 ASSESSMENT REPORT

PHY415115 - PHYSICS

GENERAL COMMENTS

Overall, the examination included a broad range of questions that required students to demonstrate knowledge of most of the course content. Students 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.

Most sections of the paper also included at least one significantly more difficult question, which gave the strongest candidates an opportunity to demonstrate their ability. The extension of each section to 45 marks (rather than 40 in recent years) also helped to provide a broader spread of marks at the higher end of the mark distributions.

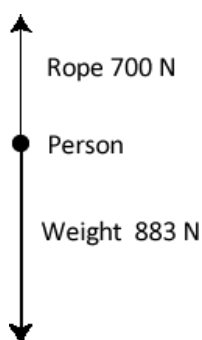
The cut off marks for each rating across all four examined criteria were decided by the Assessment Panel and are presented in the table below:

Part	A – Newtonian Physics (Criterion 5)	B – Electromagnetism (Criterion 6)	C – Wave Motion (Criterion 7)	D – Twentieth Century (Criterion 8)
Threshold mark for:	Out of 45 marks	Out of 45 marks	Out of 45 marks	Out of 45 marks
A	36	34.5	34	38
B	26	22	26	29
C	14	12	15	13.5

PART A - CRITERION 5 (NEWTONIAN PHYSICS)

QUESTION 1a

Answer



Marking notes

- Two opposing vectors were required.
- 0.5 mark deducted if vectors were the same length.

Marker's comments

This question was generally well done.

QUESTION 1b

Answer

Maximum upward force on person is 700 N.

$$\begin{aligned}F_{\text{net}} &= ma \\ &= +700 - 90 \times 9.81 \\ &= -183 \text{ N or } 183 \text{ N down, so} \\ a &= 183 / 90 \\ &= \underline{2.03 \text{ m s}^{-2} \text{ down}}\end{aligned}$$

Marking notes

- Stating sum of forces: 1 mark.
- Use of $F = ma$: 1 mark
- Including direction: 0.5 mark.

Marker's comments

Many students neglected to find the sum of the forces and just used 700N to give an answer of 7.71 ms^{-1} .

QUESTION 1c

Answer

Using $2as = v^2 - u^2$, where $u = 0 \text{ m s}^{-1}$,

$$v = \underline{4.03 \text{ m s}^{-1}} \text{ when reaching the ground.}$$

Marking notes

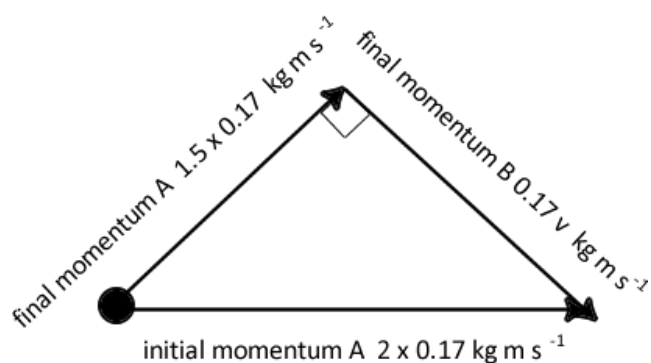
- Not including formula: subtract 0.5 marks
- Use of $a = -9.81 \text{ ms}^{-2}$ subtract one mark

Marker's comments

Completed well, overall. Many students carried an error forward from a previous part. A significant number did not take the square root of v^2 .

QUESTION 2a

Answer



Marking notes

- Vector diagram must include pointers, and right angle: subtract 0.5 mark
- Velocity diagram is acceptable as mass is constant.

Marker's comments

Pointers and labels were the main issues.

QUESTION 2b

Answer

Using Pythagoras' Theorem on the momentum diagram:

$$mv = m\sqrt{2^2 - 1.5^2} = m\sqrt{1.75} \quad \text{gives } v = \underline{1.32 \text{ m s}^{-1}}$$

Marking notes

- One dimensional consideration of momentum received 0 marks.

Marker's comments

Most students used Pythagoras, while others used the Cosine Rule. One dimensional calculation was common.

QUESTION 2c

Answer

Angle of B using trigonometry:

$$\sin q = 1.5/2$$

$$\text{therefore } \underline{q = 48.6^\circ}$$

Marking notes

- One mark was subtracted for use of incorrect trigonometric identity.

Marker's comments

Untidy diagrams often led to poor choice of trigonometric identities.

QUESTION 2d

Answer

$$\begin{aligned} E_k \text{ of A before collision:} &= \frac{1}{2} \times 0.17 \times 2^2 \\ &= 0.34 \text{ J} \end{aligned}$$

$$\begin{aligned} \text{After collision:} \quad \text{Total } E_k &= \frac{1}{2} \times 0.17 \times (1.32^2 + 1.5^2) \\ &= 0.34 \text{ J} \end{aligned}$$

Kinetic Energy is conserved so it is an elastic collision.

Marking notes

- Calculations of E_k before and after collisions were required for full marks.
- Half mark was awarded if answered correctly but without explanation.

Marker's comments

Conservation of momentum was a common wrong answer.

QUESTION 3a

Answer

As the aircraft is not accelerating vertically, but only horizontally, Newton's Second Law implies that the vertical forces must be balanced. That is, the vertical forces must add to zero.

Marking notes

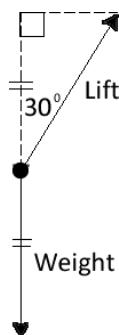
- Explanations needed to reference and state either Newton's First or Second Laws and apply them to the plane.
- Not naming the relevant Newton's Law: subtract 0.5 mark
- Using Newton's Third Law: 0 marks awarded.

Marker's comments

Students used sentences such as, "an object in motion will stay in motion" without referring to vertical acceleration of the plane.

QUESTION 3b

Answer



Marking notes

One mark was subtracted for any of the following:

- Errors in direction of F_{lift} and F_g .
- Multiple use of lift vectors along the wing.
- Inclusion of centripetal force as an additional force rather than the net force.

Marker's comments

The errors listed above were commonplace.

QUESTION 3c

Answer

From the diagram above,

$$\begin{aligned}\tan 30^\circ &= F_{\text{un}}/mg \quad \text{thus} \\ F_{\text{net}} &= mg \tan 30^\circ \\ &= \underline{5097 \text{ N inwards}}\end{aligned}$$

Marking notes

- One mark was subtracted for incorrect trigonometry or any incorrect transformation of formulae.

Marker's comments

4410N was a common wrong answer. Incorrect force diagrams in part b often led to an error in this part.

QUESTION 3d

Answer

$$F_{\text{net}} = mv^2 / r$$

$$\text{therefore } v^2 / r = 5.66$$

$$\text{so, } r = \underline{700 \text{ m}}$$

Marking notes

- Full marks for errors carried forward from part c.

Marker's comments

This question was generally well done.

QUESTION 4a

Answer

Using Kepler's Third Law in its ratio form: $\frac{T_1^2}{T_2^2} = \frac{r_1^3}{r_2^3}$ where Elektra is 1 and Earth is 2

$$\begin{aligned} \text{Hence } r_{\text{Elektra}} &= r_{\text{Earth}} (T_{\text{Elektra}}/T_{\text{Earth}})^{2/3} \\ &= \underline{4.69 \times 10^8 \text{ km}} \end{aligned}$$

Marking notes

- One mark was awarded for the correct formula and communication.
- One mark was awarded for correct answer and units.

Marker's comments

Most students used the ratio form of Kepler's Law. Substituting into the full version occasionally got the correct answer, but most students who attempted this approach subsequently made errors.

QUESTION 4b

Answer

$$v = 2\pi r/T$$

$$\begin{aligned} \text{so } v &= 2\pi \times 5.01 \times 10^5 / 1.19 \times 24 \times 3600 \\ &= 30.6 \text{ m s}^{-1} \end{aligned}$$

$$\begin{aligned} \text{Hence, } a &= v^2 / r \\ &= 30.6^2 / 5.01 \times 10^5 \\ &= \underline{1.87 \times 10^{-3} \text{ m s}^{-2}} \end{aligned}$$

Marking notes

- One mark was awarded for the correct formula and communication.
- One mark was awarded for correct answer and units.

Marker's comments

Generally, well done.

QUESTION 4c

Answer

The gravitational field strength will equal the local acceleration: $g = 1.87 \times 10^{-3} \text{ N kg}^{-1}$

Marking notes

Full marks were awarded for either a derived answer, or for using the answer from part b.

Marker's comments

Generally, well done.

QUESTION 4d

Answer

$$g = GM/r^2$$

$$\begin{aligned} \text{thus } M &= gr^2 / G \\ &= 1.87 \times 10^{-3} \times (5.01 \times 10^5)^2 / 6.67 \times 10^{-11} \\ &= \underline{7.04 \times 10^{18} \text{ kg}} \end{aligned}$$

Marking notes

- One mark was awarded for the correct formula.
- One mark was awarded for working and communication.
- One mark was awarded for correct answer and units.
- One mark was subtracted if the radius was not squared in the calculation.

Marker's comments

Generally, well done.

QUESTION 5a

Answer

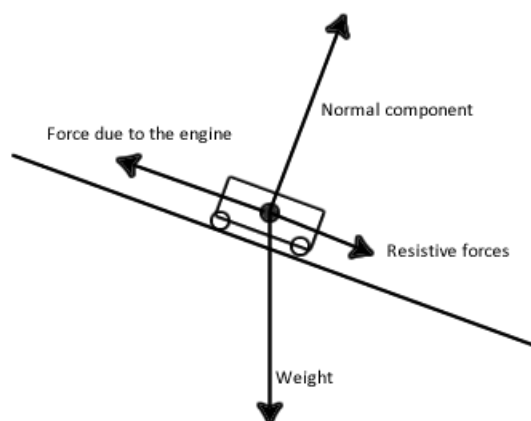


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Marking notes

- 0.5 marks deducted for any missing, extra or incorrect vectors.

QUESTION 5b

Answer

i) In one second, truck advances up the hill 2 m, so the height gained

$$h = 2 \sin 20^\circ$$

$$= 0.684 \text{ m}$$

$$E_p \text{ gain} = mgh$$

$$= 0.684 \times 5 \times 10^4 \times 9.81$$

$$= \underline{3.35 \times 10^5 \text{ J each second}}$$

ii) Work done against resistive force = $F_R \times \text{distance}$

In one second, distance travelled = 2 m

$$\text{WD} = 1/10 \times mg \times 2$$

$$= 0.1 \times 5 \times 10^4 \times 9.81 \times 2$$

$$= \underline{9.81 \times 10^4 \text{ J each second}}$$

Marking notes

- i) 0 marks for calculation of kinetic energy.
- ii) 0 marks for using $E = Fs \cos \theta$.
- ii) 0.5 marks for calculating work per meter against friction (rather than power).
- ii) One mark deducted for using mass instead of weight in the calculation of resistive force.

QUESTION 5c

Answer

Total energy each second gaining height and overcoming resistive force = sum of above

$$= 4.33 \times 10^5 \text{ J}$$

$$= 433 \text{ kJ}$$

Therefore, percentage power to move the truck up the hill = $433 \times 100/550$

$$= 78.7\%$$

Marking notes

- Only one mark awarded if only one change of energy included. Both gravitational potential energy gained and energy required to overcome resistance were needed for full marks.

QUESTION 6a

Answer

Inverse square law of gravitational field near a single mass: $g = GM / r^2$ applies.

So, C, being closest to the centre of Jupiter, will have a significantly larger value of g than B, which in turn will have a larger value of g than A.

Marking notes

- Full marks required referencing the equation, and a statement that there is a non-linear change in gravitational field strength from one side of comet to the other as it approaches Jupiter.

Marker's comments

Most students commented on a difference in g due to a difference in r . Few mentioned the significant, non-linear change.

QUESTION 6b

Answer

If the comet is not particularly strong, C will be attracted more and hence could break away from the rest of the comet. The same is true for the potential of B to separate from A.

Marking notes

- Full marks were awarded for stating that the difference in forces experienced between the three points will lead to acceleration between them, and if these forces exceed the force holding the comet together then it will break apart.

Marker's comments

Generally, well done.

QUESTION 6c

Answer

The points A and C will try to move in different orbits, A will travel too quickly while C will travel too slowly. A will try to move outwards while C will be dragged inwards. The comet will be stretched and possibly fall apart.

Marker's comments

This question was not well understood by most students.

PART B - CRITERION 6 (ELECTROMAGNETISM)

QUESTION 7a

Answer

$$\begin{aligned}V &= \frac{4}{3} \pi r^3 \\ &= \underline{3.08 \times 10^{-18} \text{ m}^3}\end{aligned}$$

Marking notes

- 0.5 marks were awarded for recognising that volume is proportional to r^3 .

Marker's comments

Not well done. Many students did not know the formula for the volume of a sphere. Students who indicated that volume was proportional to the cube of the radius received part marks.

QUESTION 7b

Answer

$$\text{Weight} = mg$$

$$m = \text{density} \times \text{volume}$$

$$= 2.90 \times 10^{-15} \text{ kg}$$

$$\text{hence weight} = \underline{2.85 \times 10^{-14} \text{ N}}$$

Marking notes

- Maximum of one mark if only mass was calculated.
- 0.5 mark deducted if mass was calculated incorrectly using volume/density.

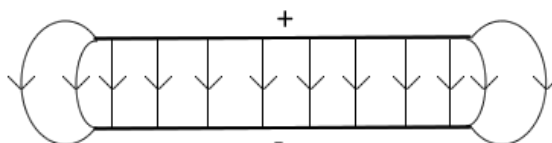
Marker's comments

Fairly well done. The main error was to calculate mass instead of weight (this received part marks).

QUESTION 7c

Answer

i)



ii) $E = V/d$

$$= 285 / 5 \times 10^{-3}$$

$$= \underline{5.70 \times 10^4 \text{ N C}^{-1}}$$

Marking notes

- i) 0 marks if field direction was incorrect.
- i) Maximum 0.5 marks if field shape was incorrect.
- ii) 0.5 marks for correct formula and substitution.
- ii) 0.5 marks for correct answer

Marker's comments

- Well done.
- Generally, well done. Some students lost 0.5 marks for using the incorrect unit or for incorrectly performing the division.

QUESTION 7d

Answer

Forces are balanced:

$$F_E = F_g$$

$$qE = mg$$

$$q = mg / E$$

$$= 2.85 \times 10^{-14} / 5.70 \times 10^4 = \underline{5.00 \times 10^{-19} \text{ C}}$$

Marking notes

- Maximum of 0.5 marks awarded if students used the $E = kq / r^2$ formula.

Marker's comments

Fairly well done. The major error was to use the formula for electric field around a point charge.

QUESTION 7e

Answer

Charge on an electron

$$e = 5.00 \times 10^{-19} / 3$$

$$= \underline{1.66 \times 10^{-19} \text{ C}}$$

Marking notes

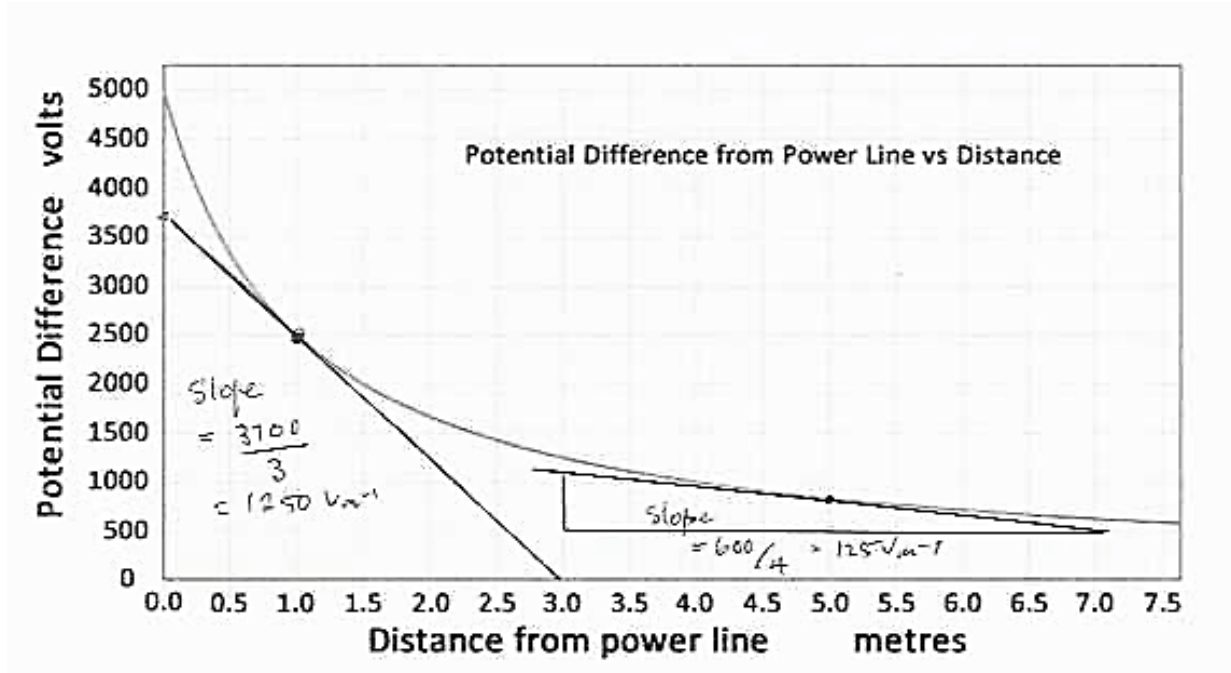
- Full marks were awarded only where the answer to (d) was divided by 3.

Marker's comments

Generally, well done.

QUESTION 8a

Answer



The potential difference can be estimated by the slope of a chord from 4.5 to 5.5 at the 5m point and 0.5 to 1.5 at the 1m point, or the slope of a tangent at the 5 m and 1 m points.

- potential difference across the feet at 5m is approximately 100 V
- and at 1m, 1200 V

Marking notes

- Full marks were awarded for a range of values (e.g., $V(0.5\text{m}) - V(1.5\text{m})$ or $V(1\text{m}) - V(2\text{m})$).
- 1.5 marks were awarded if values were read straight from the graph (2500 V and 800 V) without finding the difference between the two feet.

Marker's comments

Poorly done. Many students just read the potential difference at the two distances straight off the graph (they obtained part marks) without considering the difference between the feet.

QUESTION 8b

Answer

- Using $I = V/R$

$$I = 100 / 1000$$

$$= \underline{0.1 \text{ A}}$$

ii) 1.2 A

Marking notes

- Full marks were awarded wherever the values from part (a) were divided by the resistance (1000 Ω).

Marker's comments

Generally, well done.

QUESTION 8c

Answer

Take small steps, or shuffle along (minimising the distance between the feet).

Marking notes

- Part marks for “don’t approach”, “use Faraday cage”, “wear insulated boots”, “switch off power”.

Marker's comments

There were a large variety of responses. A small number of suggestions were quite dangerous. Full marks were awarded for suggesting that the technician shuffle / use small steps. Part marks were awarded for a simple “don’t” or for suggestions that were logical but not practical.

QUESTION 9a

Answer

The relevant law is Coulomb's Inverse Square Law for charges so values for $1/r^2$ should be calculated for the x axis.

Distance (mm)	1.00	1.50	2.00
Force measured ($\times 10^{-3} \text{ N}$)	9.92	4.41	2.48
$1/r^2$ ($\times 10^6 \text{ m}^{-2}$)	1	0.44	0.25

Marking notes

- Full marks were awarded for a suitable modification of a variable: either $1/r^2$ or \sqrt{F} .

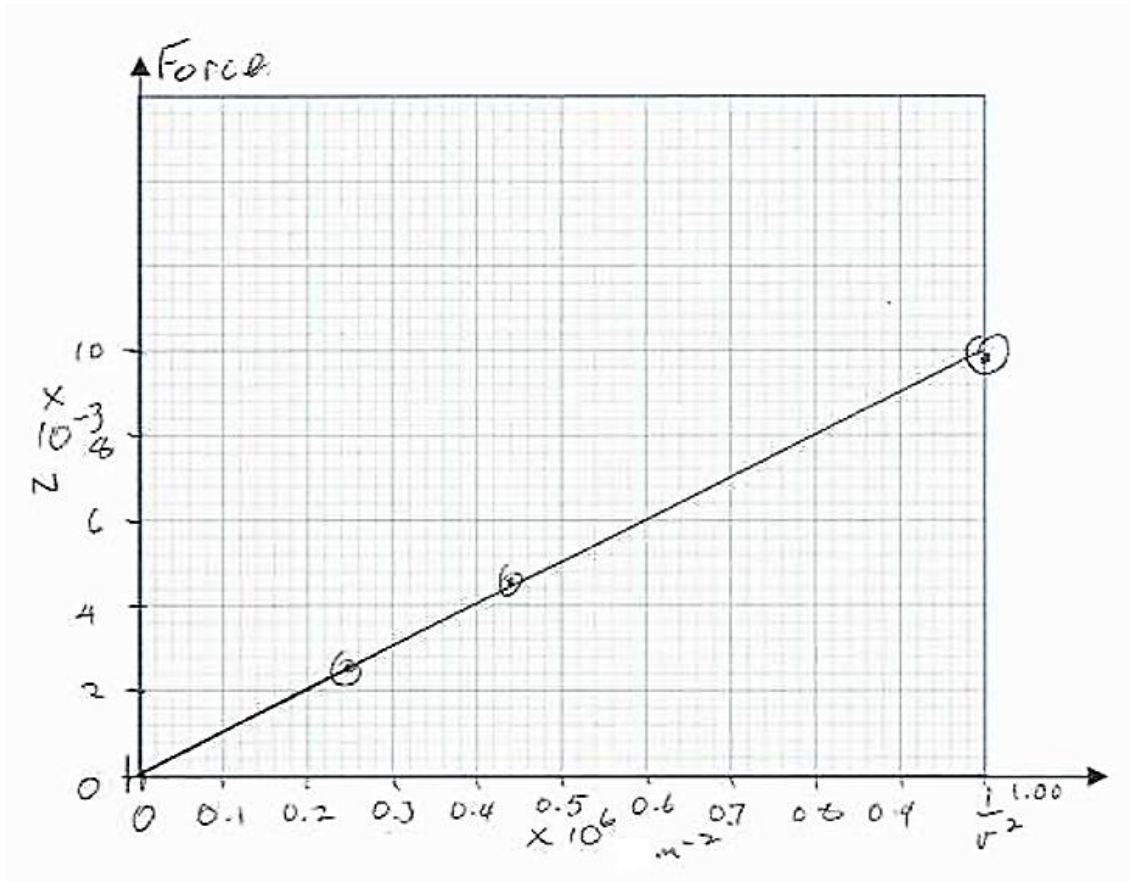
- 1.5 marks were awarded for using r^2 rather than $1/r^2$.

Marker's comments

Overall, this question was not done well. Many students made mistakes when converting mm^2 to m^2 and many were unsure how to transform the data to obtain a straight line. The main errors were to multiply or divide the force and distance values. Students who squared the radius without taking the inverse were awarded part marks.

QUESTION 9b

Answer



Marking notes

- Maximum of 1.5 marks were awarded if units were missing or incorrect.
- Maximum of 1 mark was awarded if the graph was not labelled.
- Maximum of 1 mark was awarded if the line of best fit was missing.

Marker's comments

Fairly well done. The main omissions were units and/or a line of best fit.

QUESTION 9c

Answer

$$\text{Slope} = k Q^2$$

$$= 1 \times 10^{-8}$$

$$\text{so } Q^2 = 1 \times 10^{-8} / 9 \times 10^9$$

$$= 1.11 \times 10^{-18}$$

$$\text{Therefore, } \underline{Q = 1.05 \times 10^{-9} \text{ C}}$$

Marking notes

- Maximum of 3 marks were awarded if there was an error in calculation.
- Maximum of 1 mark was awarded if only the gradient was determined.

Marker's comments

Responses to this question were mixed. Students received part marks for determining the gradient of their graph (regardless of what they had plotted). Some students ignored the graph and calculated the charge from one or more of the data points. These students also obtained part marks.

QUESTION 10

Answer

a) WXYZ, clockwise (by RHR).

b) 90° rotation implies a force of $F_B = 9 \times 2.67 \times 10^{-3} \text{ N}$ on each active side.

$$\text{Hence } F_B = 0.0240 \text{ N on each side.}$$

c) Force on each turn = $0.0240 / 20$

$$= 1.20 \times 10^{-3} \text{ N}$$

As $F_B = ILB \sin q$ for one turn,

$$I = 1 \text{ amp,}$$

$$L = 0.01 \text{ m}$$

$$q = 90^\circ$$

$$\text{so } B = F_B / IL$$

$$= \underline{0.12 \text{ T}}$$

Marker's comments

A range of errors occurred with many assuming that as an angle was involved, sin of this was obligatory when the side was at 90° to the field, not 90° of rotation. Other errors included

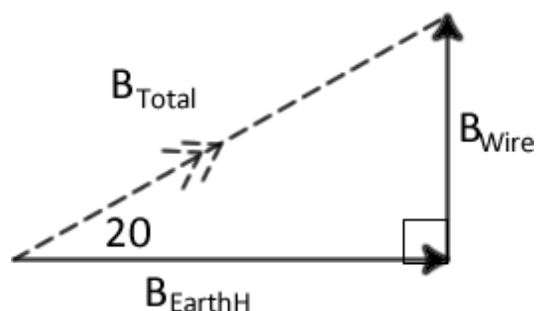
deciding that the length of conductor in the field was the whole square rather than 1 cm, 20 times over. Few students achieved full marks.

QUESTION 11

Answer

$$\begin{aligned} \text{a) } B &= kl/r \\ &= 2 \times 10^{-7} \times 5 / 0.2 \\ &= 5.00 \times 10^{-6} \text{ T west (by RHR)} \end{aligned}$$

b)



From the vector field diagram, $\tan 20^\circ = B_{\text{wire}} / B_{\text{HE}}$

$$\begin{aligned} \text{hence } B_{\text{HE}} &= 5 \times 10^{-6} / \tan 20^\circ \\ &= \underline{1.37 \times 10^{-5} \text{ T}} \end{aligned}$$

$$\begin{aligned} \text{c) } \cos 70^\circ &= B_{\text{HE}} / B_{\text{E}} \\ \text{so } B_{\text{E}} &= 1.37 \times 10^{-5} / \cos 70^\circ \\ &= \underline{4.00 \times 10^{-5} \text{ T}} \end{aligned}$$

Marker's comments

This question was not completed well, as few set up the vectors correctly. This was demonstrated in part a) when students failed to give the field of the wire as pointing west. With this failure, the subsequent calculations were very poorly done with inappropriate equations applied or poor trigonometry used.

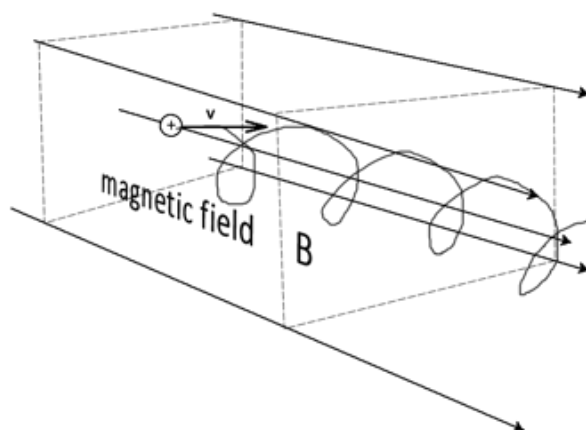
QUESTION 12

Answer

$$\begin{aligned} \text{a) } r &= mv \sin \theta / qB \\ &= 2 \times 10^{-27} \times 1.67 \times 10^{-27} \times 0.866 / 1.60 \times 10^{-19} \times 3.7 \times 10^{-6} \\ &= \underline{4.89 \times 10^5 \text{ m or 489 km}} \end{aligned}$$

b) Higher mass protons have huge gyromagnetic radii in very weak fields so are likely to escape while electrons having a smaller mass are more likely to remain in the field.

c)



Helix - forward component of velocity means they will advance as well as circle.

- d) The magnetic force has a component in the backward direction.
- e) The particle will start moving backwards as the field pinches inwards due to the backwards component of the magnetic force.

Marker's comments

Part a) was generally well done, but with a few students using the mass of electrons rather than protons and a few students giving the charge of a proton as "1" rather than 1.6×10^{-19} C.

Part b) was speculative, with few students actually suggesting a reason.

In part c), most gave some form of spiral.

In parts d) and e), very few showed that the force was at 90° to the field line and was therefore pointing somewhat upwards. This gives a force BACK on the particle causing it to eventually spiral back away from the pole.

PART C - CRITERION 7 (WAVE MOTION)

QUESTION 13a

Answer

- i) upwards
- ii) A is stationary as it is at the top of the wave
C is stationary as it is at the bottom of the wave
D is moving at highest speed downwards
- iii) A and C

Marking notes

- i)
- 1 mark was only awarded for “upwards”, or “up”.
 - 0.5 marks were awarded for “up/down” (must be both, not just “down”) or “perpendicular to motion”.
- ii)
- 1 mark for stating that A and C are stationary.
 - 1 mark for stating reasoning (momentarily stationary while changing direction).
 - 0.5 marks for stating that D has non-zero velocity.
 - 0.5 marks for stating that D’s velocity is downwards.
- iii)
- 0.5 marks each for A and C.

Marker’s comments

- i) This question was generally poorly done, given the relative simplicity of the question. Many students interpreted the wave motion as a translation of a fixed wire shape to the right.
- ii) Those students who understood the nature of the transverse wave scored well in this question. Many other students misinterpreted the wave as a standing wave, scoring very few marks as a result.
- iii) A low proportion of students achieved full marks for this question, even amongst those who achieved full marks for question 13a ii.

QUESTION 13b

Answer

i)



Reflected pulse is inverted and moves to the left, transmitted pulse is upright.

- ii) $v = \sqrt{\frac{T}{\mu}}$ As T is the same for the whole system, speed depends on μ , so transmitted pulse is slower than the reflected pulse because the linear mass density is greater in the heavier rope.

Marking notes

- i)
 - 0.5 marks for showing a reflected pulse
 - 0.5 marks if the reflected pulse was out of phase
 - 0.5 marks for showing a transmitted pulse
 - 0.5 marks if the transmitted pulse is in phase
- ii)
 - 0.5 marks for identifying a slower transmitted pulse
 - 0.5 marks for stating that the pulse will travel more slowly in the heavier (or denser) medium
 - 1 mark for justifying via the equation for wave speed in a string

Marker's comments

- i) A majority of students scored full marks on this question. Marks were not allocated to correctly interpreting the pulse lengths and/or amplitudes of the reflected and transmitted pulses, but 0.5 marks were deducted if the pulse lengths were grossly incorrect (i.e., if the transmitted pulse was shown with a significantly larger pulse length than the reflected pulse).
- ii) Most students identified that the transmitted pulse would travel more slowly than the reflected pulse. However, many attempted to justify the difference using energy considerations or Newton's Second Law, rather than identifying that the wave speed is a property of the medium. A significant number of students argued that the shorter wavelength of the transmitted pulse caused the slower wave speed, rather than vice versa.

QUESTION 14a

Answer

The pipe is closed at one end, so the length $L = \lambda/4$

$$\lambda = 4 \times 0.17$$

$$= 0.68 \text{ m}$$

$$v = \lambda f \quad \text{so} \quad f = v/\lambda$$

$$= 354 / 0.68$$

$$= 520 \text{ Hz}$$

Marking notes

- 1 mark for calculating the wavelength correctly.

- 1 mark for calculating frequency from wavelength.
- 0.5 marks deducted for using 344 ms^{-1} as the speed of sound, rather than the given 354 ms^{-1}

Marker's comments

A large majority of students answered this question correctly.

QUESTION 14b

Answer

As the pipe is closed at one end, the ratios of the frequencies will be 1:3:5. So Sequence 2 is correct.

Marking notes

- 0.5 marks for identifying Sequence 2.
- 1 mark for stating that the frequencies follow a pattern of $f_0, 3f_0, 5f_0, \dots$
- 0.5 marks for linking the pattern to a closed-ended pipe (possibilities included simply mentioning the closed-ended pipe, drawing the corresponding standing wave patterns, or stating the relevant wavelength-to-pipe length relationships).

Marker's comments

Most students answered this question correctly.

QUESTION 14c

Answer

$$l = v/f$$

$$= 354 / 260$$

$$= 1.36 \text{ m}$$

$$\text{So, length } L = 1.36 / 4$$

$$= 0.34 \text{ m}$$

Marking notes

- 1 mark for the correct answer
- 0.5 marks deducted for using 344 ms^{-1} instead of 354 ms^{-1} (but not if already penalised in 14a)
- 0.5 marks deducted for using a pipe length of a half-wavelength rather than a quarter-wavelength

Marker's comments

Most students answered this question correctly.

QUESTION 14d

Answer

The length of the pipe doesn't change, so the wavelength doesn't change.

Hence $l = 1.36 \text{ m}$

$$\begin{aligned}\text{And so } v_{\text{helium}} &= lf \\ &= 1.36 \times 750 \\ &= \underline{1021 \text{ m s}^{-1}}\end{aligned}$$

Marking notes

- 1 mark for finding/using the correct wavelength
- 1 mark for calculating the correct speed based on the wavelength
- 0.5 marks deducted for using 344 ms^{-1} instead of 354 ms^{-1} (but not if already penalised in 14a or 14b)

Marker's comments

Most students answered this question correctly.

QUESTION 15a

Answer

- i) $AX = v_2 t$
- ii) $BY = v_1 t$

Marking notes

- i)
 - 1 mark for $d = v_2 \times t$
 - 0.5 marks for $d = v_2/t$ or just $d = v_2$
- ii)
 - 1 mark for $d = v_1 \times t$
 - 0.5 marks for $d = v_1/t$ or just $d = v_1$

Marker's comments

Not well done – many students somehow deduced that $s = v/t$. Most, however, correctly connected AX with v_2 and BY with v_1 .

QUESTION 15b

Answer

$\angle BAY = q_i$ angle of incidence

$\angle AYX = q_R$ angle of refraction

Marking notes

- 1 mark for $\angle BAY$ being equal to the angle of incidence
- 1 mark for $\angle AYX$ being equal to the angle of refraction
- 0.5 marks deducted for each of these for $90^\circ \pm$ the relevant angle
- 0.5 marks deducted overall for correct answers with un-simplified working.

For example : $\angle BAY = 90 - (90 - \text{angle of incidence})$

Marker's comments

This part of Question 15 was well answered by most of the students that attempted Question 15.

QUESTION 15c

Answer

In $\triangle AYX$: $\sin \angle AYX = AX / AY$

That is, $\sin q_R = v_2 t / AY$

In $\triangle BAY$: $\sin \angle BAY = BY / AY$

That is, $\sin q_i = v_1 t / AY$

Taking a ratio: $\sin q_i / \sin q_R = (v_1 t / AY) / (v_2 t / AY)$

Cancelling gives: $\sin q_i / \sin q_R = v_1 / v_2$

Marking notes

- 1 mark for $\sin(\angle BAY) = v_1 \times t / AY$
- 1 mark for $\sin(\angle AYX) = v_2 \times t / AY$
- 1 mark for subsequent (successful and correct) algebraic manipulation to get to the required formula
- 1 mark deducted if t was not included in the above
- 2 marks deducted if $\sin(\angle BAY) = v_1$ and $\sin(\angle AYX) = v_2$
- 2 marks deducted for inappropriate use of the sine rule (because the angles are not in the same triangle)
- No penalty for using a placeholder for AY (e.g., x or H)

Marker's comments

A significant number of students successfully followed the clues provided in previous parts and were able to achieve at least 2 marks overall. A similarly significant number did not attempt the question.

QUESTION 16a

Answer

$$\begin{aligned}\sin q_c &= 1/n \\ &= 1/2.42 \\ &= 0.413 \text{ so } q_c = \sin^{-1}(0.413) \\ &= \underline{24.4^\circ}\end{aligned}$$

Marking notes

- Maximum of 0.5 marks awarded if Snell's law was incorrectly applied.
- 1.5 marks were awarded to students whose calculator was in radian measure.

Marker's comments

The major error present in students' responses was incorrect application of Snell's law by trying to find the non-existent critical angle for the air-diamond boundary.

QUESTION 16b

Answer

- As the ray is exactly turned through a total of 180° , at the first boundary it is turned through 90° so the angle of incidence is 45° .
- The angle of incidence is greater than the critical angle at both diamond /air boundaries, so all light is sent back along the return path. It is therefore very bright.

Marking notes

- 1 mark for 45°
 - 0.5 marks was awarded for the response of 0° based on the air-diamond boundary
- 1 mark for total internal reflection, or for stating the angle of incidence was greater than the critical angle.

Marker's comments

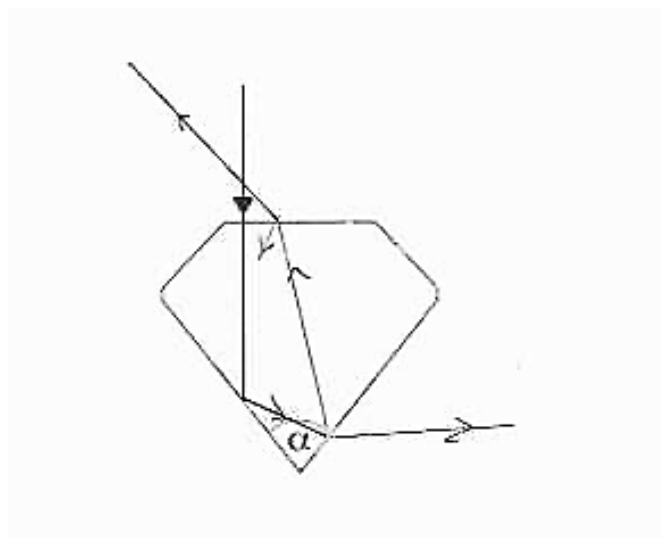
- This question proved challenging to most students. The most common answer was to assume the angle of incidence was equal to the critical angle.

ii) This question was generally done well.

QUESTION 16c

Answer

As the angle at the diamond – air interface at the bottom clearly exceeds the critical angle, light will be internally reflected to the next face across angle a , where it may not exceed the critical angle. Here, some light may be refracted out of the crystal while the remainder will go to the top face where most will be refracted out.



Marking notes

- 1 mark for reflection on 1st and 2nd boundary interactions.
- 1 mark for refraction on second boundary, showing $\theta_r > \theta_i$.
- Assuming total internal reflection on second boundary was accepted, as long as refraction was shown to occur on the third boundary interaction.
- Marks were deducted for showing refraction on the first diamond-air boundary as the θ_i must have been greater than the critical angle.

Marker's comments

This question was poorly done. The best responses used a ruler, and showed the normal to each boundary indicating angle relationships.

QUESTION 17a

Answer

- Beating – two sources slightly out of phase with each other leading to alternate constructive and destructive interference.
- 336 and 344 Hz

Marking notes

- i)
 - 1 mark for 'beats' or 'beating'.
 - 1 mark for superposition of waves or constructive and destructive interference.
- ii)
 - 0.5 marks each.

Marker's comments

This question was well done by most students.

QUESTION 17b

Answer

The frequencies must be exactly the same, and the waves must be in phase with each other.

Marking notes

- 1 mark for same wavelength or frequency.
- 1 mark for in phase.

Marker's comments

Many students attempted to describe the coherent phase relationship between the sources using colloquial terminology such as 'in time' or 'harmonised'. Part marks were awarded if the language was specific enough to convey meaning.

QUESTION 17c

Answer

Bandwidth of the sound pattern is 1.32m

$$W = \lambda \times d$$

$$d = 3.5 \text{ m}$$

$$\lambda = 10 \text{ m}$$

$$\text{So, } \lambda = Wd / \lambda$$

$$= 1.32 \times 3.5 / 10$$

$$= 0.462 \text{ m}$$

$$\text{Hence, } f = v / \lambda$$

$$= 344 / 0.462$$

$$= \underline{745 \text{ Hz}}$$

Marking notes

- 1 mark for $\lambda = 0.462 \text{ m}$
- 1 mark for $f = 745 \text{ Hz}$

Marker's comments

This question was well done. The most common error was misidentifying the x and d in the formula.

QUESTION 17d

Answer

If the speakers are moved closer together, then d is smaller and hence W is larger. The antinode positions move further apart.

Marking notes

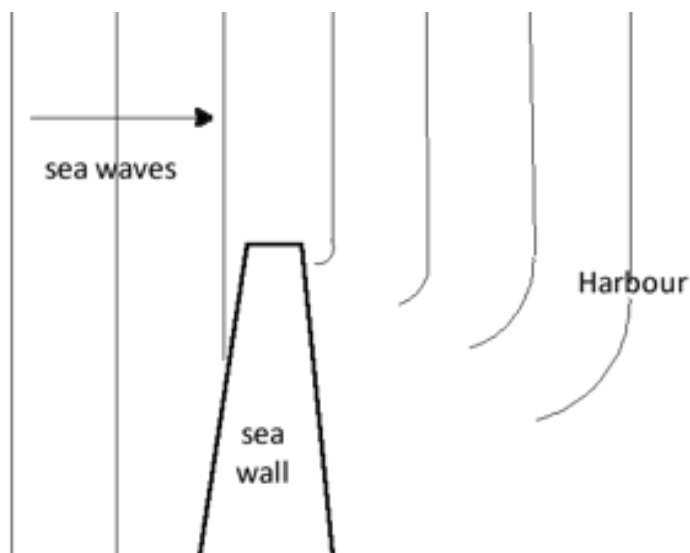
- 1 mark for bandwidth will increase.
- 1 mark for justification.

Marker's comments

This was well done.

QUESTION 18a

Answer



Marking notes

- 0.5 marks for consistent wavelength matching the incident sea waves.
- 0.5 marks for general shape of the diffraction pattern.
- 1 mark for diffraction around the point including a shadow area.

Marker's comments

This was not well done with a large percentage of students showing no shadow area.

QUESTION 18b

Answer

Diffraction.

Marking notes

- 1 mark for diffraction.
- 0.5 marks for Huygen's principle.

Marker's comments

This was well done.

QUESTION 18c

Answer

550 nm

Marking notes

- 1 mark for anything between 400 – 700nm.

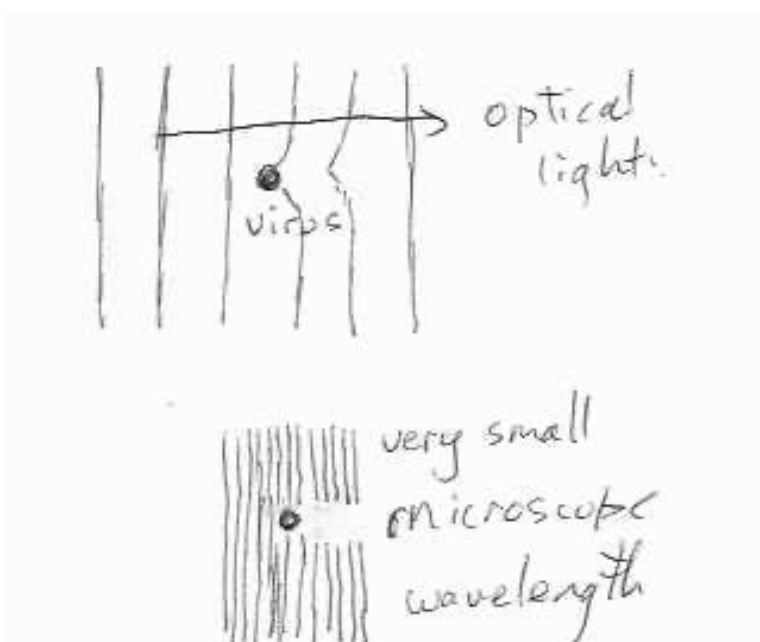
Marker's comments

This was well done.

QUESTION 18d

Answer

i)



Light diffracts around the virus as it is significantly smaller than the wavelengths of ordinary light. The shadow of the virus does not therefore reach the eyepiece of the microscope.

- ii) Radiation wavelength must be significantly smaller than 100 nm. X-ray radiation has wavelengths of about 1 nm so would not diffract markedly giving an image.

Marking notes

- i)
- 2 marks were awarded to students who said the wavelength of visible light was longer than the size of the virus and hence the light would diffract around the virus.
 - 1.5 marks for explanations involving reflection.
 - 0.5 marks was awarded to students who simply stated that the wavelength of light was larger than the size of the virus. This was the most common response.
- ii)
- 0.5 marks for UV, X-ray or electron microscope.
 - 0.5 marks for justifying that the shorter wavelength would allow for reflection back off the virus or that it would not diffract around the virus.

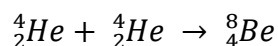
Marker's comments

- i) This question was very challenging for students.
- ii) Very few students were awarded full marks in this question, as responses specifically required reasoning.

PART D - CRITERION 8 (TWENTIETH CENTURY)

QUESTION 19a

Answer



Marker's comments

This question was well done by most students. The most common error was adding “+energy” to the wrong side of the equation.

QUESTION 19b

Answer

$$\begin{aligned}\text{Mass difference} &= \text{Mass of Be isotope} - 2 \times \text{mass He isotope} \\ &= 8.005305 - 2 \times 4.00260\end{aligned}$$

$$= 0.000105 \text{ u}$$

Energy associated with this = 931×0.000105

$$= \underline{0.098 \text{ MeV}}$$

Marker's comments

Generally, well done. The most common error was dividing the mass difference by 931 MeV, instead of multiplying.

QUESTION 19c

Answer

Mass of the Be-8 isotope is greater than the mass of the reactants, so energy is required.

Marker's comments

Generally, well done. The most common error was to state that energy was released, even though the mass difference indicated that energy is required.

QUESTION 19d

Answer

Binding energy = mass defect \times 931

Mass defect = $4 (1.008665 + 1.007277) - 8.005305$

$$= 0.058463 \text{ u}$$

Binding energy = 0.058463×931

$$= 54.4 \text{ MeV}$$

Binding energy / nucleon = $54.4 / 8$

$$= \underline{6.80 \text{ MeV nucleon}^{-1}}$$

Marker's comments

Moderately well done by students. Some students included electrons in their calculations and others didn't – there was no explicit direction on which to do, although the question's emphasis on nuclei provided a clue. The most common error was using the answer to (b) and dividing it by 8.

QUESTION 19e

Answer

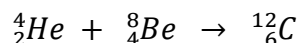
Extremely hot, so that the high kinetic energy of the particles provides a chance of overcoming their electrostatic repulsion. Also dense, so the chances of some absorption occurring are reasonable.

Marker's comments

Generally, well done by most students. The most common error was being able to state the factors but not explain why.

QUESTION 19f

Answer



Marker's comments

Generally, well done by most students. The most common errors were putting the equation backwards and putting energy on the wrong side of the equation.

QUESTION 19g

Answer

$$\begin{aligned}\text{Mass difference} &= \text{Mass He} + \text{Mass Be} - \text{Mass C} \\ &= 8.005305 + 4.00260 - 12.0000000 \\ &= 0.007905 \text{ u}\end{aligned}$$

$$\begin{aligned}\text{Energy emitted} &= 0.007905 \times 931 \\ &= \underline{7.36 \text{ MeV}}\end{aligned}$$

Marker's comments

Generally, well done by most students. The most common errors were not calculating energy at all (from mass difference), and dividing by 931 MeV rather than multiplying.

QUESTION 19h

Answer

A gamma photon.

Marker's comments

Generally, well done by most students.

QUESTION 20a

Answer

$$\begin{aligned}A &= \frac{0.693 N}{T_{1/2}} \\ \text{so } N &= \frac{A T_{1/2}}{0.693} \\ &= (4.4 \times 10^9 \times 138.4 \times 24 \times 3600) / 0.693 \\ &= 7.59 \times 10^{16} \text{ atoms}\end{aligned}$$

$$\begin{aligned}
 \text{mass} &= N M / N_A \\
 &= 7.59 \times 10^{16} \times 210 / 6.02 \times 10^{23} \\
 &= 2.65 \times 10^{-5} \text{ gram} \\
 &= 26.5 \text{ mg}
 \end{aligned}$$

Marker's comments

Generally, well done by most students. The most common errors were miscalculation of the half-life when converting it to seconds, or errors in transposing the equation.

QUESTION 20b

Answer

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

$$\text{so } A_0 = A e^{\lambda t}$$

$$= 4.4 \times 10^9 \times e^{0.693 \times 60 / 138.4}$$

$$= 5.94 \times 10^9 \text{ Bq}$$

$$= 5.94 \text{ GBq}$$

Marker's comments

Generally, well done by most students. The most common errors were miscalculation of the half-life when converting it to seconds, or incorrectly re-calculating the decay constant instead of using the value from a).

QUESTION 21a

Answer

- i) Increase the photocurrent, as more electrons are ejected.
- ii) The threshold frequency will not change as this is a function of the metal being illuminated.

Marker's comments

Well done by students.

QUESTION 21b

Answer

$$\text{Work Function} = hf_0$$

$$\text{thus } f_0 = 4.3 / 4.14 \times 10^{-15}$$

$$= \underline{1.04 \times 10^{15} \text{ Hz}}$$

Marker's comments

Generally, well done by most students. The most common errors occurred when students incorrectly converted eV to Joules or used the wrong value for h.

QUESTION 21c

Answer

$$\begin{aligned}E_{\max} &= hf - hf_0 \\ &= hc / \lambda - 4.3 \\ &= (4.14 \times 10^{-15} \times 3 \times 10^8) / 1.85 \times 10^{-7} - 4.3 \text{ eV} \\ &= \underline{2.41 \text{ eV}}\end{aligned}$$

Marker's comments

Generally, well done by most students.

QUESTION 21d

Answer

Wavelengths associated with infrared light are below the threshold frequency of all metals so these photons will trigger photoelectric emission. They therefore cannot be used to detect warm objects emitting only infrared light.

Marker's comments

Generally, well done by most students.

QUESTION 22a

Answer

Ionization energy is from $n = 1$ to infinity so it is 13.59 eV.

$$\text{In joules: } 13.59 \times 1.60 \times 10^{-19} = \underline{2.18 \times 10^{-18} \text{ J}}$$

Marker's comments

Generally, well done by most students. Some students didn't take from $n=1$ to $n=\infty$. Surprisingly many students have trouble converting eV to J.

QUESTION 22b

Answer

$$\begin{aligned}DE &= 3.40 - 1.51 \text{ eV} \\ &= 1.89 \text{ eV}\end{aligned}$$

$$DE = hc / \lambda$$

$$\text{So, } \lambda = hc / DE$$

$$= 4.14 \times 10^{-15} \times 3 \times 10^8 / 1.89$$

$$= \underline{657 \text{ nm}}$$

Marker's comments

Generally, well done by most students. Some students changed to Joules incorrectly, resulting in an answer that didn't respond to the value given. Some students had meaningless working, but just wrote 660nm as the answer. No marks were awarded unless some working was shown.

QUESTION 22c

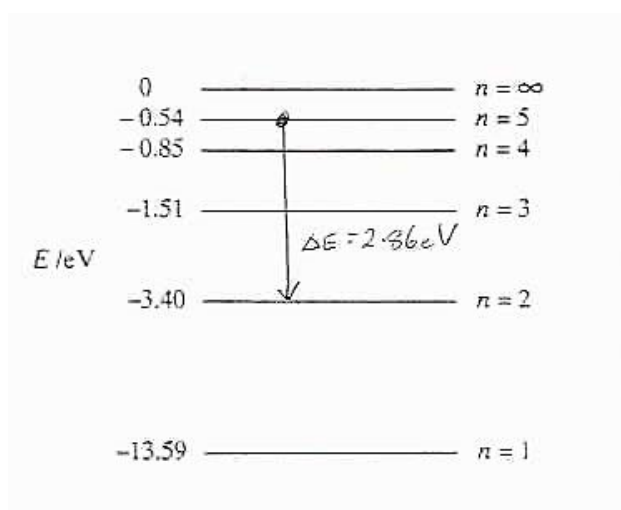
Answer

Transition corresponding to 434 nm:

$$DE = hc / \lambda$$

$$= 4.14 \times 10^{-15} \times 3 \times 10^8 / 434 \times 10^{-9}$$

$$= 2.86 \text{ eV corresponds to } n = 5 \text{ to } n = 2$$



Marker's comments

Generally, well done by most students. The most common errors were the use of Plank's constant for Joules and being unable to correctly convert Joules to eV. Some students tried to show transitions in the emission spectrum rather than using the energy level diagram on the previous page.

QUESTION 22d

Answer

- i) Ultraviolet.
- ii) Infrared.

Marker's comments

Well done by some students. Some students correctly calculated the energy emitted but were not able to interpret the EM spectra correctly (for example $\lambda = 9.13 \times 10^{-8}$ to $1.21 \times 10^{-7} \text{ m}$ are all in the UV range (not X-ray). Half marks were awarded. Students also commonly calculated $\lambda = 8.28 \times 10^{-7} \text{ m}$ but did not realise that this is in the IR range.

QUESTION 23a

Answer

$$\begin{aligned}\lambda_T &= \frac{2.90 \times 10^{-3}}{T} \\ &= 2.90 \times 10^{-3} / 50 \\ &= 5.80 \times 10^{-3} \text{ m}\end{aligned}$$

Marker's comments

Well done by most students.

QUESTION 23b

Answer

Infrared.

Marker's comments

Well done by most students.

QUESTION 23c

Answer

Visible light will have wavelength increased into the infrared.

Marker's comments

Well done by some students. Many students were unable to correctly explain how the redshift affects the wavelength.

QUESTION 23d

Answer

Radiation from the telescope itself must be as low as possible in the infrared region to minimise overwhelming signals from the astronomical objects being studied in the infrared.

Marker's comments

Very few students could connect the practical reason a reduced temperature of the telescope would have on picking up signals in the IR spectrum. Some students correctly stated that blackbody radiation was emitted from the telescope but then proceeded to say that the telescope needed to emit IR radiation to detect its own radiation and did not seem to realise

that the telescope needed to be cooled down to minimise interference with the signals from astronomical objects.

QUESTION 24a

Answer

$$qV = hc / \lambda$$

$$\text{so } \lambda = hc / qV$$

$$= (6.63 \times 10^{-34} \times 3 \times 10^8) / (1.6 \times 10^{-19} \times 5 \times 10^4)$$

$$= \underline{24.8 \text{ pm}}$$

Marker's comments

Well done by most students. Errors resulted from transposition errors rather than lacking understanding. Students and teachers should note that working out, rearranging formulae and substituting in values with calculations are required for 'show that' questions.

QUESTION 24b

Answer

$$p = h / \lambda$$

$$= 6.63 \times 10^{-34} / 2.48 \times 10^{-11}$$

$$= \underline{2.67 \times 10^{-23} \text{ kg m s}^{-1}}$$

Marker's comments

Well done by most students. The most common error was the use of the incorrect version of Planck's constant when calculating momentum.

QUESTION 24c

Answer

- i) If the current is increased, the intensity of the X-ray emissions will increase but the minimum wavelength will remain the same.
- ii) If the potential difference is increased, then the minimum wavelength will get smaller and the intensity will rise due to more total energy being available in the form of kinetic energy.

Marker's comments

- i) Well done by most students.
- ii) Well done by most students. Many students correctly identified that the minimum wavelength would decrease but did not realise emitted x-rays would increase with increasing voltage.