Assessment Schedule – 2023

Scholarship Physics (93103)

Evidence Statement

Q	Evidence	1–4 marks	5–6 marks	7–8 marks
ONE (a)	**Rutherford's model:** The atom has a small, strongly charged nucleus, surrounded by a cloud of lightweight particles of opposite charge. • Most α-particles **travel straight through / have a small deflection** as the **nuclei are small / atom is mostly empty space** so the α-particles miss them by a long way. • **Scattering** is mostly due to the **concentrated charge** of the nucleus. • Some **α-particles are reflected** because the **nucleus contains most of the mass** of the atom. So, it is heavy enough to reflect the α-particles back the way they came with no noticeable deflection of the nucleus itself.	Thorough understanding of these applications of physics. OR Partially correct mathematical solution to the given problems. OR Partial understanding of these applications of physics.	(Partially) correct mathematical solution to the given problems. OR Reasonably thorough understanding of these applications of physics.	Correct mathematical solution to the given problems. AND Thorough understanding of these applications of physics.
(b)(i)	At the position of closest approach, the α-particle will momentarily come to a stop, and all the kinetic energy will be converted to potential energy. Kinetic energy of alpha particle = ½ mv^2 $\frac{1}{2}mv^2 = \frac{kq_1q_2}{r}$ Substituting for $q_1 = 2e$, $q_2 = Ze$, and $r = D$ $\frac{1}{2}mv^2 = \frac{k2eZe}{D}$ Rearranging, $D = \frac{4kZe^2}{mv^2}$			
(ii)	$D = \frac{4kZe^2}{mv^2} = \frac{2kZe^2}{\frac{1}{2}mv^2}$ $= \frac{2kZe^2}{4.78\times10^6\times1.60\times10^{-19}}$ $= \frac{2\times8.99\times10^9\times79\times(1.60\times10^{-19})^2}{4.78\times10^6\times1.60\times10^{-19}}$ $= \frac{2\times8.99\times10^9\times79\times(1.60\times10^{-19})}{4.78\times10^6}$ $= 4.75\times10^{-14}$ m Or uses E_k to determine v and substitutes for the same result.			
(c)	As the incoming α-particle directly approaches the nucleus, the nucleus will be repelled and start moving in the same direction as the α-particle, with both having kinetic energy. Therefore, the total kinetic energy will never go to zero, and so the maximum potential energy will be less. This means that the distance of closest approach will be larger.			
(d)(i)	Nuclei with higher binding energy per nucleon (close to the peak of the BEpN curve) are more stable, so nuclei smaller than Fe-56 will tend to undergo fusion to join into larger nuclei. So, in this case, we would expect a fusion reaction,			

	which is Reaction 1.			
(ii)	For a nuclear reaction to occur, the incoming α-particle has to actually penetrate the nucleus. A higher kinetic energy allows the particle to get closer to the nucleus. Also, any excess kinetic energy from the incoming α-particle will be available to promote the nuclear reaction (even in cases where the reaction is endothermic).			

Q	Evidence	1–4 marks	5–6 marks	7–8 marks
TWO (a)	After release, the horizontal distance covered is $d + L\sin\theta$. The horizontal velocity is $v\cos\theta$, so we have, $t \times v\cos\theta = d + L\sin\theta$ Substituting $t = \frac{2v\sin\theta}{g}$ $\frac{2v\sin\theta}{g} \times v\cos\theta = d + L\sin\theta$ $v^2 = \frac{g(d + L\sin\theta)}{2\sin\theta\cos\theta}$ $v = \sqrt{\frac{g(d + L\sin\theta)}{2\sin\theta\cos\theta}}$	Thorough understanding of these applications of physics. OR Partially correct mathematical solution to the given problems. OR Partial understanding of these applications of physics.	(Partially) correct mathematical solution to the given problems. OR Reasonably thorough understanding of these applications of physics.	Correct mathematical solution to the given problems. AND Thorough understanding of these applications of physics.
	For the axe to rotate through $\theta + 2\pi$ radians after release, $\omega t = \theta + 2\pi$, and $\omega = \frac{v}{L}$ So $t = \frac{\theta + 2\pi}{\frac{v}{L}}$ Substituting $t = \frac{2v\sin\theta}{g}$ $v^2 = \frac{(\theta + 2\pi)Lg}{2\sin\theta}$ From (a), $v^2 = \frac{g(d + L\sin\theta)}{2\sin\theta\cos\theta}$ $\frac{(\theta + 2\pi)Lg}{2\sin\theta} = \frac{g(d + L\sin\theta)}{2\sin\theta\cos\theta}$ $\theta + 2\pi = \frac{2\sin\theta g(d + L\sin\theta)}{2Lg\sin\theta\cos\theta} = \frac{(d + L\sin\theta)}{L\cos\theta} = \frac{(\frac{d}{L} + \sin\theta)}{\cos\theta}$ $\frac{d}{L} = (\theta + 2\pi)\cos\theta - \sin\theta$ OR Alternate method: linear distance = angle × distance linear distance $= \left(\theta + 2\pi\right)L\cos\theta$ horizontal distance $= d + L\sin\theta$ $d + L\sin\theta = \left(\theta + 2\pi\right)L\cos\theta$ $d = \left(\theta + 2\pi\right)L\cos\theta - L\sin\theta$ $d = L\left(\left(\theta + 2\pi\right)\cos\theta - \sin\theta\right)$ $\frac{d}{L} = \left(\theta + 2\pi\right)\cos\theta - \sin\theta$			
(c)	For small θ, the θ term is insignificant compared to 2π so can be ignored. Also, $\sin\theta$ is small compared to $2\pi\cos\theta$, so the sin term will have negligible effect on the expression and can be ignored. $\frac{d}{L} = 2\pi\cos\theta$			

(d)(i)	For the throw to be successful, the ratio $\frac{d}{L}$ needs to stay the same. So Mika would need to stand slightly further away from the target.			
(ii)	On the moon, the condition for the release angle would be unaltered, as it has no dependence on g. However, the velocity would decrease (proportional to $\sqrt{g}$), the time of flight would increase (proportional to $\frac{1}{\sqrt{g}}$), and the rotational frequency would decrease (proportional to v). So, the flight would be the same, but in slow motion.			

Q	Evidence	1–4 marks	5–6 marks	7–8 marks
THREE (a)	Kirchoff's current rule (conservation of charge), Kirchoff's voltage rule (conservation of energy). Names, descriptions or symbolic ok.	Thorough understanding of these applications of physics. OR Partially correct mathematical solution to the given problems. OR Partial understanding of these applications of physics.	(Partially) correct mathematical solution to the given problems. OR Reasonably thorough understanding of these applications of physics.	Correct mathematical solution to the given problems. AND Thorough understanding of these applications of physics.
(b)(i)	Lamp does not light up, so $I_3 = 0\ A$, so $I_1 = I_2 = I$ LHS loop: $2.0 - 0.5I = 0$ $I = \frac{2.0}{0.5} = 4.0\text{ A}$ Outside loop: $2.0 - 0.5I - 1.2I + V = 0$ (Assuming P is positive end, so V is positive.) $V = 1.7I - 2.0 = 1.7 \times 4.0 - 2.0 = 4.8\text{ V}$ Positive answer, indicating the assumption was correct and point P is positive.			
(ii)	No current flows through lamp as there is no potential difference across the lamp. This would not change if the resistance of the lamp changes, so the lamp will still not light up.			
(c)	$f' = f\frac{v_\text{w}}{v_\text{w} - v_\text{s}}$ (source approaching). Want $f' = 2f$, so we need $\frac{v_\text{w}}{v_\text{w} - v_\text{s}} = 2 \Rightarrow v_\text{s} = \frac{v_\text{w}}{2}$ To find where this happens use $v_\text{f}^2 = v_\text{i}^2 + 2ad$ Where d is the distance travelled. In this example, the car starts from rest so $v_\text{i} = 0$. Inserting $v_\text{f} = \frac{v_\text{w}}{2}$ and rearranging we get $d = \frac{v_\text{w}^2}{8a}$ The car must start *at least* this far away, so $d > \frac{v_\text{w}^2}{8a}$			

(d)(i)	The sound produced by the horn is Doppler shifted to a higher frequency / shorter wavelength in the direction the car is travelling, and to a lower frequency / longer wavelength in the direction opposite to the direction the car is moving.			
(ii)	Beat frequency between any two adjacent harmonics = fundamental frequency for open-open pipe $f_B = f_1 = 4.76$ Hz $\lambda = \frac{v}{f} = \frac{343}{4.76} = 72.06$ m Length of tunnel, $L = \frac{\lambda}{2} = \frac{72.06}{2} = 36.03$ m $\lambda_n = \frac{2L}{n}, f_n = \frac{v_w}{\lambda} = \frac{v_w n}{2L}$ $f_{20} = \frac{343 \times 20}{2 \times 36.03} = 95.2$ Hz $f_{21} = \frac{343 \times 21}{2 \times 36.03} = 100.0$ Hz Approaching Doppler frequency = 100 Hz, receding Doppler frequency = 95.2 Hz Combining these values with the known speed of sound, and $f'_{approach} = \frac{f v_w}{v_w - v_s}$ and $f'_{recede} = \frac{f v_w}{v_w + v_s}$ *gives* $v_s = 8.37 \text{ m s}^{-1}$ and $f = 97.5$ Hz			

<table>
<tr><th>Question</th><th>Evidence</th><th>1–4 marks</th><th>5–6 marks</th><th>7–8 marks</th></tr>
<tr><td>FOUR
(a)(i)</td><td>$Q = n \times e \times \text{volume}$
$= 8.49 \times 10^{28} \times 1.60 \times 10^{-19} \times 0.100 \times 0.0200 \times 0.00100$
$= 27\,168 \text{ C}$
$t = \frac{Q}{I} = \frac{27\,168}{0.25} = 108\,672 \text{ s}$
$v = \frac{\Delta d}{\Delta t} = \frac{0.100}{108\,672} = 9.20 \times 10^{-7} \text{ m s}^{-1}$</td><td rowspan="6">Thorough understanding of these applications of physics.
OR
Partially correct mathematical solution to the given problems.
OR
Partial understanding of these applications of physics.</td><td rowspan="6">(Partially) correct mathematical solution to the given problems.
OR
Reasonably thorough understanding of these applications of physics.</td><td rowspan="6">Correct mathematical solution to the given problems.
AND
Thorough understanding of these applications of physics.</td></tr>
<tr><td>(ii)</td><td>$\left[neAv_{\text{d}}\right] = \text{m}^{-3}.\text{C}.\text{m}^{2}.\text{m s}^{-1} = \text{C s}^{-1} = \text{A} = \left[I\right]$</td></tr>
<tr><td>(b)</td><td>Electrons flow R to L (opposite to direction of conventional current). Using RH rule the force on a moving electron is towards side Q, making side P positively charged (or equivalent explanation).</td></tr>
<tr><td>(c)(i)</td><td>Magnetic force pushes electrons towards side Q, so Q is negatively charged and P is positively charged. Electrons also experience an electrostatic force repelling them from the negative charge on side Q and attracting them toward the positive charge on side P. This balances the magnetic force on the electron.</td></tr>
<tr><td>(ii)</td><td>$F_{\text{mag}} = Bqv = Bev_{\text{d}} = Be\frac{I}{neA} = \frac{BI}{nA}$
$F_{\text{elec}} = Eq = Ee = \frac{V_{\text{H}}}{w}e = \frac{V_{\text{H}}e}{w}$
$F_{\text{mag}} = F_{\text{elec}}$
$\frac{BI}{nA} = \frac{V_{\text{H}}e}{w}$
$V_{\text{H}} = \frac{BIw}{nAe} = \frac{BIw}{nwde}$
$V_{\text{H}} = \frac{BI}{nde}$</td></tr>
<tr><td>(d)</td><td>Most precise B will require the most precise measurement of V_{H}. Larger values of V_{H} can be measured more precisely. To maximise V_{H} we need:
• Maximum B and I.
• Minimum n and d.
Limitations of this method are that low values of n and d will mean the conductor has large resistance. A large current flowing through a large resistance will result in a lot of power loss in the conductor, heating (and possibly damaging) it.</td></tr>
</table>

Cut Scores

Scholarship	Outstanding Scholarship
18 – 26	27 – 32