**2021 JC2 H2 Preliminary Examination Paper 2 Suggested Solutions**

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| **1** | **(a)** | | The principle of conservation of linear momentum states that the total momentum of a system of interacting bodies remain constant provided no external force acts on the system. | 1<br>1 |
| | **(b)** | **(i)** | By the principle of conservation of momentum,<br>$m_X u_X + m_Y u_Y = m_X v_X + m_Y v_Y$<br>4.0(500) + 28.0(340) = 4.0(220) + 28.0($v$)<br><br>$v$ = 380 m s$^{-1}$ | <br><br>1<br><br>1 |
| | | **(ii)** | Relative speed of approach = $u_X - u_Y$ = 500 – 340 = 160 m s$^{-1}$<br>Relative speed of separation = $v_Y - v_X$ = 380 – 220 = 160 m s$^{-1}$<br>Since the relative speeds of approach and separation are the same, the collision is elastic.<br><br>Or<br>Check whether total final kinetic energy equals the total initial kinetic energy. | 1<br><br>1 |
| | | **(iii)** | The forces on the two bodies (or on X and on Y) are equal in magnitude and opposite in direction<br>The duration of impact for both forces is the same and force is change in momentum / time | 1<br><br>1 |

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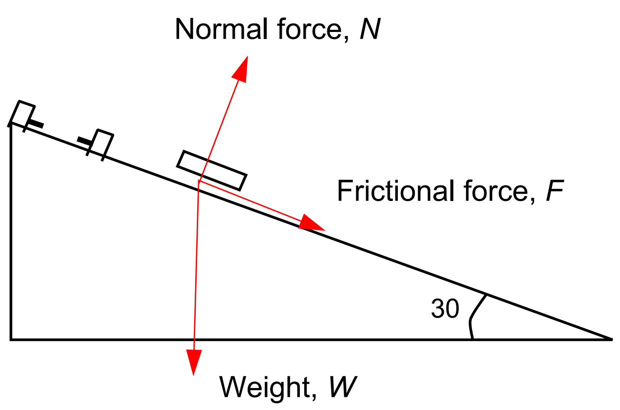
| 2 | (a) | On a banked track, the normal contact force by the road on the car will be tilted to the vertical at an angle equal to the angle of inclination of the track.<br>The horizontal components of both the normal force and the frictional force by the road on the car contributes to the required centripetal force to keep the car moving in a circular path. This increases the centripetal force, which would otherwise be provided by just the frictional force alone. | 1<br>1 |
| | (b) (i) | <br>**[1]** – One mark for each correct force.<br>*** Allow two normal contact forces and two friction forces between the two wheels and the road.**<br>*** Minus [1] for not naming any force in full**<br>*** Minus [1] if centripetal force is drawn into diagram** | 3 |

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| | (ii) | Horizontally, the resultant force towards the centre of the circle is the centripetal force,<br>$N\sin 30^\circ + F\cos 30^\circ = \frac{mv^2}{r}$<br>$0.5N + 6000\frac{\sqrt{3}}{2} = \frac{1000v^2}{50}$<br>$N = 40v^2 - 10392.3 - - - -(1)$<br>Vertically, there is no resultant force,<br>$N\cos 30^0 - F\sin 30^0 - mg = 0$<br>$\frac{\sqrt{3}}{2}N - 6000(0.5) - 1000(9.81) = 0$<br>$N = \frac{2}{\sqrt{3}}(3000 + 9810)$<br>$N = 14791.7$<br>Substituting into (1),<br>$14791.7 = 40v^2 - 10392.3$<br>$v = 25$ or $25.1$ m s$^{-1}$ | 1<br>1<br>1 |

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| **3** | **(a)** | | Internal energy is the sum of microscopic kinetic energy and potential energy of all the molecules in the gas | **1** |
| | | | Microscopic potential energy for a real gas is not equal to zero as there is intermolecular bonding between the molecules. So internal energy is not only dependent on temperature. | **1** |
| | **(b)** | | $p = \frac{1}{3}\rho\langle c^2\rangle \quad = \frac{1}{3}\frac{M}{V}\langle c^2\rangle$ , where $M$ = total mass of the ideal gas, $V$ = total volume of the ideal gas | **1** |
| | | | $\frac{3}{2}pV = \frac{1}{2}M\langle c^2\rangle$ | |
| | | | $\frac{3}{2}nRT = \frac{1}{2}M\langle c^2\rangle$ = Total KE of gas | **1** |
| | | | Since internal energy, $U$ = total KE of ideal gas, as PE of ideal gas = 0 | **1** |
| | | | $\therefore U \propto T$ | |
| **4** | **(a)** | **(i)** | $pV = NkT$ | |
| | | | $(2.5 \times 10^5) \times (3.8 \times 10^{-2}) = N \times (1.38 \times 10^{-23}) \times (181 + 273)$ | **1** |
| | | | $N = 1.5 \times 10^{24}$ | **1** |
| | | **(ii)** | From first law of thermodynamics, increase in internal energy = heat energy supplied + work done on the system | |
| | | | Since the process took place at constant volume, work done = 0 | **1** |
| | | | Thus, increase in internal energy = 2700 + 0 = 2700 J | **1** |
| | | | (Since it is an increase in the internal energy, the change in internal energy is positive 2700 J) | |
| | **(b)** | | $\Delta E_K = 3/2\ N\ k\ (\Delta T)$ | |
| | | | $2700 = 3/2\ (1.5 \times 10^{24})\ (1.38 \times 10^{-23}) \times \Delta T$ | **1** |
| | | | $\Delta T = 87$ | |
| | | | $T = 181 + 273 + 87 = 541$ K | **1** |
| **5** | **(a)** | **(i)** | Given $I = nAve$, | |
| | | | since $I$, $n$, $e$ are the same for cross-sections X and Y, | |
| | | | $\frac{v_Y}{v_X} = \frac{A_X}{A_Y} = \frac{\pi d_X^2/4}{\pi d_Y^2/4} = \frac{d_X^2}{d_Y^2}$ | 1 |
| | | | $= (\frac{d}{0.72d})^2 = 1.93$ | 1 |
| | | **(ii)** | $R = \frac{\rho l}{A} = \frac{(1.12 \times 10^{-6})(4 \times 10^{-3})}{\pi(\frac{(0.72 \times 0.21 \times 10^{-3})^2}{4})}$ | 1 |
| | | | $= 0.250\ \Omega$ | 1 |

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| | | (iii) | When the cross-sectional area is smaller, its resistance per unit length is larger.<br>With the same current through entire wire,<br>the voltage per unit length of the damaged part is larger. | 1 |
| | (b) | (i) | $I_1 + I_3 = I_2$ | 1 |
| | | (ii) | p.d. across BJ of wire changes<br>so there is a difference between the p.d across wire points BJ and p.d. across cell E | 1<br>1 |
| | | (iii) | $V_{BF} = \dfrac{R_2}{R_1 + R_2 + r_1} \times E_1 = \dfrac{3.5}{3.0 + 3.5 + 1.5} \times 4.5 = 1.96875\ \text{V}$<br>$\dfrac{l_{BJ}}{l_{BF}} = \dfrac{E_2}{V_{BF}} \Rightarrow l_{BJ} = \dfrac{E_2}{V_{BF}} \times l_{BF} = \dfrac{1.2}{1.96875} \times 1.0 = 0.610\ \text{m}$ | 1<br>1<br>1 |

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| 6 | (a) | **Faraday's law** of electromagnetic induction states that the **magnitude** of the induced e.m.f. *E* is directly proportional to the rate of change of the magnetic flux linkage. | | **1** |
| | (b) | (i) | Rate of increase in area of loop ABDCA<br>= [3-(-5)] $\times$ 0.15 = 1.2 m$^2$ s$^{-1}$<br>Induced e.m.f. = $\dfrac{d\phi}{dt}$ = (0.20)(1.2)<br>= 0.24 V<br><br>Alternatively,<br>$\varepsilon = Blv_{AB} + Blv_{CD}$<br>= 0.20(0.15)(3) + 0.20(0.15)(5)<br>= 0.24 V | **1**<br>**1**<br>**1** |
| | | (ii) | [The magnetic flux $\phi = BA$.] Since the area of the loop is increasing, the magnetic flux is increasing. By Lenz's law, the induced current in the loop will create a magnetic field that is acting out of the paper to oppose the increasing flux.<br>By the right hand grip rule, the induced current will flow in the anti-clockwise direction of ABDCA<br>(Cannot use Fleming's Right Hand Rule as an explanation in this case as question specifies using Lenz's law.) | **1**<br>**1** |
| | | (iii) | By Fleming's Left Hand rule, the induced current will lead to a magnetic force that is in opposite direction to the velocity of the rods. This will cause the rod to slow down. | **1** |

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| | | | In order to keep the speed constant such that the net force is zero, an external force (equal and opposite) is required to counter the magnetic force. | 1 |

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| 7 | (a) | 1. | The existence of a threshold (minimum) frequency below which no photoelectrons are emitted no matter how intense the EM radiation is. | 1 |
| | | 2. | Above the threshold frequency, the maximum kinetic energy of the photoelectron (stopping potential) increases with the frequency and is independent of the intensity. | 1 |
| | | 3. | There is no appreciable time delay between the incident EM radiation and the emission of photoelectrons even for very low EM intensities. | 1 |

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| | (b) | (i) | Work function energy refers to the minimum energy required to liberate an electron (escape) from the metal surface. | 1 |
| | | (ii) | Photon energy = $\frac{hc}{\lambda}$<br>$= \frac{(6.63\times10^{-34})(3.00\times10^{8})}{380\times10^{-9}}$<br>$= 5.23 \times 10^{-19}$<br>$= 3.27$ eV | 1<br><br>1 |
| | | (iii) | Sodium and calcium (both must be listed) (allow ecf)<br>The incident photon has energy greater than their work function energies | 1<br>1 |
| | (c) | | From de Broglie's equation, $p = \frac{h}{\lambda}$<br>$p = \frac{6.63\times10^{-34}}{380\times10^{-9}}$<br>$= 1.74\times10^{-27}$ N s<br>From Newton's 2nd law<br>$F = \frac{\Delta p_{total}}{\Delta t} = \frac{N}{t}\Delta p$<br>(rate of photons incident on metal)(change in momentum for one photon)<br>$= (7.6 \times 10^{14})(1.74\times10^{-27})$<br>$= 1.3 \times10^{-12}$ N | 1<br><br>1<br><br>1 |

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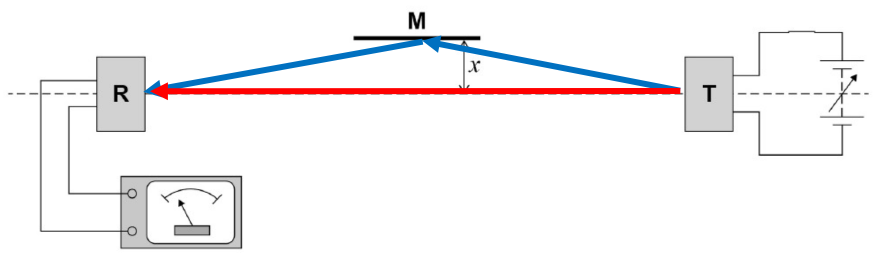
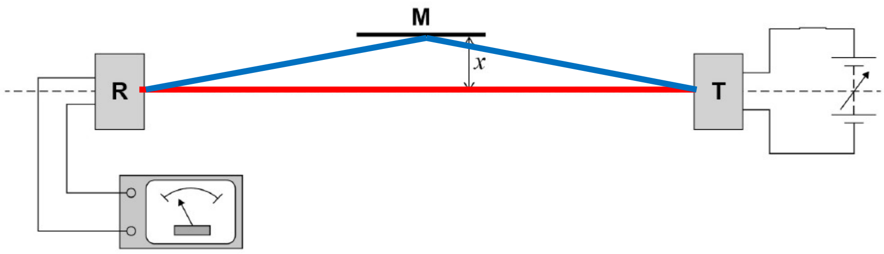
| **8** | **(a)** | | π radians | **1** |
| | **(b)** | **(i)** | <br><br>Award 1 mark for each correct path. | **2** |
| | **(b)** | **(ii)** | Resultant displacement/amplitude is the vector sum of the resultant displacement/amplitude of the waves.<br>(It is "considering", hence, do not need to be too strict on the words)<br>The two waves reaching the receiver have different amplitude/energy/ power/intensity.<br>Because (any one of the possible reasons)<br>1. the distance travelled by the two waves are different.<br>2. some energy is absorbed upon reflection.<br>Hence no complete cancellation / resultant displacement/amplitude is not zero. | **1**<br>**1**<br>**1** |
| | **(c)** | **(i)** | Measure the distance of the two ends of plate M<br>And adjust (make sure) plate M such that the two ends are equidistant from the marked line.<br>OR<br>Use a set square to align a ruler to be perpendicular to the reference line.<br>Move the set square along the ruler to align plate M at the new position. | **1**<br>**1** |

**(ii)** Recognising the path difference

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| | | | Path difference = $2z - y$<br>1 mark to recognise the path difference | **1** |
| | | | $= 2\sqrt{x^2 + \left(\frac{y}{2}\right)^2} - y$<br>1 mark to be able to write the equation in terms of the hypothenuse of the triangle | **1** |
| | | | $= \sqrt{4x^2 + (y)^2} - y$<br>Since there is a <u>phase change at the surface</u>, for <u>destructive interference</u><br>Path difference = $n\lambda$<br>1 mark to explain why path difference is equated to $n\lambda$ | **1** |

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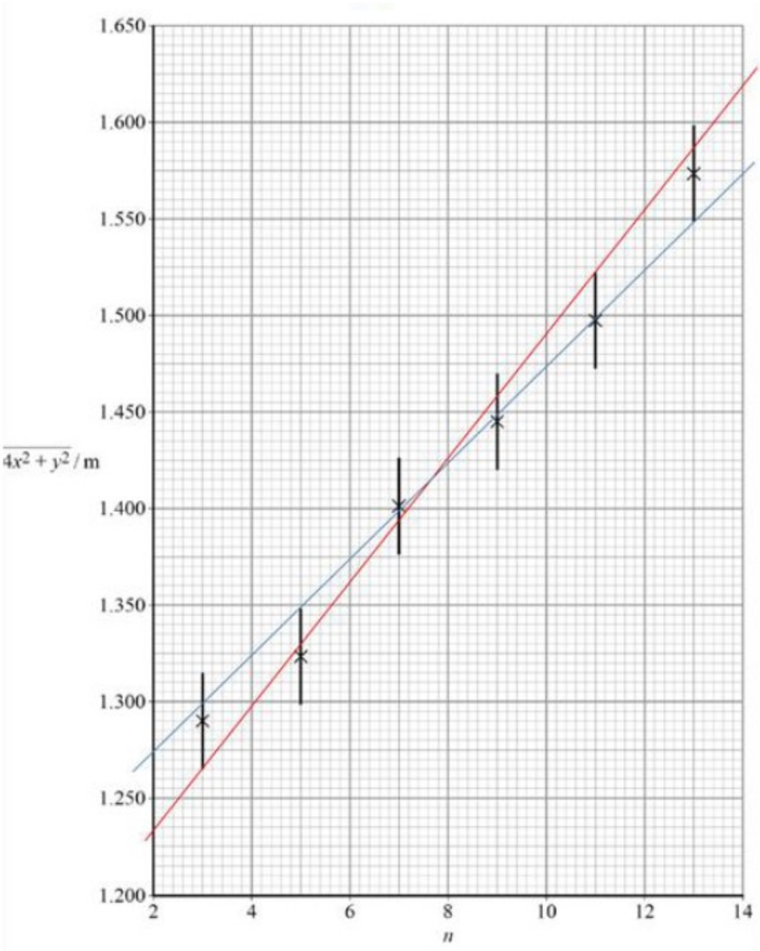
| | **(d)** | **(i)** | <br><br>$G_{max}$ line is drawn through bottom of *n*=3 error bar and through top of *n*=11 error bar.<br>Gradient $G_{max}$ = 0.0312 to 0.0327 | **1**<br>**1** |
| | | **(ii)** | $G_{min}$ line is drawn through top of *n*=5 error bar and through bottom of *n*=13 error bar.<br>Gradient $G_{min}$ = 0.0242 to 0.0257 | **1**<br>**1** |
| | | **(iii)** | average $\lambda = \frac{G_{max}+G_{min}}{2}$<br>Allow ECF | **1** |
| | | **(iv)** | It is in band C. (allow ecf) | **1** |

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| | | **(v)** | $\Delta\lambda = G_{max} - \lambda_{ave} = 0.36 \times 10^{-2}$<br>Percentage uncertainty in $\lambda = \frac{\Delta}{\square} \times 100$<br>= 12.6 %<br>Allow ECF | **1**<br><br>**1** |
| | **(e)** | | $y = kx$<br>$4.5 = k_1\,(2.9)$ $22.3 = k_2\,(5.8)$ $55.5 = k_3\,(9.0)$ $99.5 = k_4\,(12.0)$<br>$k_1 = 1.5$ $k_2 = 3.8$ $k_3 = 6.1$ $k_4 = 8.29$<br><br>Conclusion: Since the *k* values are significantly different, *y* is not proportional to *x*.<br>(1 mark for showing at least two *k* values with correct calculation<br>1 mark for conclusion) | **1**<br><br>**1** |
| | **(f)** | | Because the wave reflecting from plate M will not reach the receiver.<br>Hence, there will not be any superposition of the waves at the receiver.<br>Or if student mentioned about angle of incidence = angle of reflection for the second mark. | **1**<br>**1** |