# Assessment Schedule – 2012

## Scholarship Physics (93103)

### Evidence Statement

| Q | Evidence | 1-4 marks | 5-6 marks | 7-8 marks |
|---|---|---|---|---|
| ONE (a)(i) | The energy of any incident photon = $hf = \frac{hc}{\lambda}$<br>The minimum energy required to liberate an electron from the metal surface is $\phi$ (the work function). Any difference between the work function energy and the incident photon energy will manifest as the maximum kinetic energy of the liberated photons.<br>$\frac{1}{2}mv^2 = \frac{hc}{\lambda} - \phi$<br>The KE of the electron can also be expressed as the equivalent electric potential energy<br>$\frac{1}{2} mv_{max}^2 = V_{max}e$ ( where $V$ = the potential (voltage) required to accelerate an electron from rest to velocity $v$ )<br>So $V_{max}e = \frac{hc}{\lambda} - \phi$ | Thorough understanding of these applications of physics.<br><br>OR<br><br>Partially correct mathematical solution to the given problems<br><br>AND / OR<br><br>Partial understanding of these applications of physics. | (Partially) correct mathematical solution to the given problems.<br><br>AND / OR<br><br>Reasonably thorough understanding of these applications of physics. | Correct mathematical solution to the given problems.<br><br>AND<br><br>Thorough understanding of these applications of physics. |
| (ii) | The classical wave explanation would expect that increasing intensity of incident radiation would lead to an increase in the $KE_{max}$ of the liberated electrons. Also light of any frequency would be capable of liberating electrons as long as sufficient time was given for the incoming energy to rise to whatever level the electrons required for liberation.<br>Experiment showed that intensity is proportional only to the numbers of electrons released and not to their $KE_{max}$ which is dependent only on the frequency of the incident light. It is also found that low intensity, high frequency light will cause electron release immediately while high intensity, low frequency light will never achieve electron liberation, no matter how much energy is delivered over any period of time. The classical explanation failed and was replaced by a model of the radiation energy being delivered in small packets, photons, whose energy depended only on their frequency. | | | |
| (b)(i) | Mass lost ($\Delta m$) = $\frac{\Delta E}{c^2} = \frac{200 \times 10^6 \times 1.6 \times 10^{-19}}{9 \times 10^{16}}$ = $3.55 \times 10^{-28}$ kg<br>The mass lost per equal mass is $1.775 \times 10^{-28}$ kg. Their original mass was $1.965 \times 10^{-25}$ kg so their rest mass is $1.963225 \times 10^{-25}$ kg. | | | |
| (ii) | Because $(1 - \frac{v^2}{c^2})$ will always be less than 1 ( for any moving mass ) the actual mass of a moving object will always be greater than the rest mass ($m_o$). The equation expresses the gain in mass any moving object undergoes. | | | |

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| (iii) | Initial mass ($M_I$) = $3.93 \times 10^{-25}$ kg ($2.2106 \times 10^5$ MeV)<br>Final mass of one part ($M_O$) = $\frac{M_I - 200\text{ MeV}}{2}$<br>($1.1043 \times 10^5$ MeV; $1.9632 \times 10^{-25}$ kg)<br>Mass of $M_O$ while moving at velocity $V$ (call it $M_M$)<br>$M_M = \frac{M_O}{\sqrt{1-\frac{V^2}{c^2}}}$<br>The KE of this $M_O$ is given by $E = \Delta Mc^2 = (M_M - M_O)c^2$<br>(The gain in KE IS the gain in mass, the $(M_M - M_O)$)<br>KE = $(M_M - M_O)c^2$<br>$100\ MeV = (\frac{M_O}{\sqrt{1-\frac{V^2}{c^2}}} - M_O)c^2$<br>$\sqrt{1-\frac{V^2}{c^2}} = \frac{M_O}{\frac{100\text{ MeV}}{c^2} + M_O} = 0.999094$<br>$1-\frac{V^2}{c^2} = 0.999094^2 = 0.99819$<br>$\frac{V^2}{c^2} = 1.8109 \times 10^{-3}$<br>$V = 0.1277 \times 10^8\text{ m s}^{-1}$ | | | |

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| TWO<br>(a)(i) | Operating resistance of bulb $= \frac{V^2}{W} = \frac{120^2}{75} = 192\ \Omega$<br>Put a 192 Ω resistor in series with the bulb. The voltage drop across each will be 240 /2 = 120 V ( the required operating voltage for the bulb )<br>The power drawn by this configuration will be<br>$240 \times \frac{75}{120} = 150$ W | Thorough understanding of these applications of physics.<br><br>OR<br><br>Partially correct mathematical solution to the given problems.<br><br>AND / OR<br><br>Partial understanding of these applications of physics. | (Partially) correct mathematical solution to the given problems.<br><br>AND / OR<br><br>Reasonably thorough understanding of these applications of physics. | Correct mathematical solution to the given problems.<br><br>AND<br><br>Thorough understanding of these applications of physics |
| (ii) | With the inductor (L) , the $V_R$ will be 90° out of step with $V_L$.<br>$V_S^2 = V_L^2 + V_R^2$<br>$V_L = \sqrt{240^2 - 120^2} = 120\sqrt{3}$<br>$X_L = \frac{V_L}{I} = \frac{120\sqrt{3}}{\left(\frac{75}{120}\right)} = 192\sqrt{3}$<br>$L = \frac{X_L}{w} = \frac{192\sqrt{3}}{2\pi \times 50} = 1.06$ H<br>Power drawn is just the 75 W dissipated by the bulb. The inductor dissipates no power. | | | |
| (b) | The AC in the coil creates a strong and fluctuating magnetic field around the iron core. This moving magnetism induces a current in the aluminium ring (an eddy current). The eddy current produces its own magnetic field, which acts in the opposite direction (is repelled by) the coil's magnetism. The repulsive force between the two can be larger than the force of gravity on the ring so the ring is moved away from the coil until it reaches a distance at which the upward magnetic repulsive force is equal to the downward gravitational force. | | | |
| (c) | Make the coil "non-inductive" by reversing the direction of the windings after half have been completed in one direction. Reverse the direction of half the windings so that the amount of clockwise current is balanced by an equal amount of anticlockwise current. | | | |
| (d) | The glue must be non conducting (and must be permeable to magnetic fields). The core must be laminated to reduce the induction of eddy currents, which would both waste a lot of energy and produce a lot of potentially damaging heat. | | | |

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| THREE (a) | In the time between each wave crest being emitted the source of the waves is moving towards the observer. This movement means that the crest-to-crest distance (the wavelength) is reduced. Since the speed of the waves through the air is constant, any reduction in the wavelength must lead to an increase in the frequency (since $v = f\lambda$). | Thorough understanding of these applications of physics.<br><br>OR<br><br>Partially correct mathematical solution to the given problems.<br><br>AND / OR<br><br>Partial understanding of these applications of physics. | (Partially) correct mathematical solution to the given problems.<br><br>AND / OR<br><br>Reasonably thorough understanding of these applications of physics. | Correct mathematical solution to the given problems.<br><br>AND<br><br>Thorough understanding of these applications of physics. |
| (b) | The frequency would increase. By moving towards a source, the observer will reach each wave crest after a shorter time interval than would be the case if the observer was stationary. The time between adjacent crests arriving is the Periodic Time ($T$) and a reduction in $T$ means an increase in frequency ($f$) (since $f = 1 / T$). | | | |
| (c) | $f_0 = \dfrac{f_S \mathrm{c}}{\mathrm{c} + v}$<br>$v = \dfrac{340(440 - 416.2)}{416.2} = 19.4426\ \mathrm{m\ s^{-1}}$<br>Distance fallen to reach that speed<br>$(d) = \dfrac{v^2}{2g} = \dfrac{378}{19.62} = 19.2668\ \mathrm{m}$<br>Number of floors fallen = $\dfrac{19.2668 - 0.7}{3.1} = 5.9893 = 6$<br>Assumptions. No air resistance so $g$ is constant. | | | |
| (d) | Line from phone to Frankie is at an angle of<br>$\tan^{-1}\left(\dfrac{40}{19.2668}\right) = 64.28°$ to the vertical.<br>Speed away from Frankie along that line is<br>$V_{\mathrm{down}} \cdot \cos 64.28 = 19.4426 \cdot 0.434 = 8.4372\ \mathrm{m\ s^{-1}}$<br>$f_0 = \dfrac{f_S \mathrm{c}}{c + v}$<br>$f_0 = \dfrac{340 \times 440}{348.4372} = 429.346 = 429\ \mathrm{Hz}$ | | | |

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| FOUR<br>(a) | $v^2 = 2gh$<br>$D$i ( drop ) = $\frac{1}{2}gt^2$<br>$D$ii (rise ) = $v\,t - \frac{1}{2}gt^2$<br>$h = D$i + $D$ii = v . t ( works dimensionally)<br>$t = \frac{h}{v}$<br>Sub into $D$i = $\frac{1}{2}\frac{gh^2}{v^2}$<br>$D$i = $\frac{\frac{1}{2}gh^2}{2gh} = \frac{1}{4}h$ | Thorough understanding of these applications of physics.<br><br>OR<br><br>Partially correct mathematical solution to the given problems<br><br>AND / OR<br><br>Partial understanding of these applications of physics. | (Partially) correct mathematical solution to the given problems.<br><br>AND / OR<br><br>Reasonably thorough understanding of these applications of physics. | Correct mathematical solution to the given problems.<br><br>AND<br><br>Thorough understanding of these applications of physics. |
| (b) | One starts off fast and loses speed – the other starts slow and gains speed. By the time they meet, the fast starting one must have done most of the traveling. They cross ¾ the way up. When they meet both have been traveling for the same time. The fast moving one must have traveled a greater distance. | | | |
| (c) | $mv = MV - \frac{mv}{3}$<br>$\frac{4mv}{3M} = V$<br>$\frac{1}{2}mv^2 = \frac{1}{2}MV^2 + \frac{1}{2}\frac{mv^2}{9}$<br>$\frac{8mv^2}{9} = \frac{M \cdot 16m^2v^2}{9M^2}$<br>$8mv^2 = \frac{16m^2v^2}{M}$<br>$M = 2m$ | | | |
| (d) | <u>Collision 1</u>: B hits C<br>Momentum $4 = V_B + V_C$<br>Restitution $0.4 = \frac{V_C - V_B}{4-0}$<br>$V_C - V_B = 1.6$<br>Gives $2V_C = 5.6$<br>$V_C = 2.8$ m s$^{-1}$ and $V_B = 1.2$ m s$^{-1}$<br><u>Collision 2</u>: A hits B<br>Momentum $4 + 1.2 = V_A + V_B = 5.2$<br>Restitution $0.4 = \frac{V_B - V_A}{4-1.2}$<br>$V_B - V_A = 1.12$<br>Gives $2V_B = 6.32$<br>$V_B = 3.16$ m s$^{-1}$ and $V_A = 2.04$ ms$^{-1}$<br>(this is the final velocity for Ball A )<br><u>Collision 3</u>: B hits C<br>Momentum $3.16 + 2.8 = 5.96 = V_B + V_C$<br>Restitution $0.4 = \frac{V_C - V_B}{3.16-2.8}$<br>$V_C - V_B = 0.144$<br>Gives $2V_C = 6.104$<br>$V_C = 3.052$ m s$^{-1}$ and $V_B = 2.908$ m s$^{-1}$<br>Since the masses are the same the conservation of momentum can be written as the conservation of velocity. Those three answers add up to 8… the starting total velocity. | | | |

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|---|---|---|---|---|
| FIVE<br>(a) | $v = \frac{2\pi R_S}{T}$<br>$g_M = \frac{GM}{R_M^2}$<br>$M = \frac{g_M R_M^2}{G}$<br>$\frac{v^2}{R_S} = \frac{GM}{R_S^2}$<br>$R_S^3 = \frac{g_M R_M^2 T^2}{4\pi^2}$<br>$R_S^3 = \frac{3.71 \times 3.395^2 \times 10^{12} \times 24.62^2 \times 3.6^2 \times 10^6}{4\pi^2}$<br>$= 8.509 \times 10^{21}$ m<br>$R_S = 2.042 \times 10^7$ m | Thorough understanding of these applications of physics.<br><br>OR<br><br>Partially correct mathematical solution to the given problems.<br><br>AND / OR<br><br>Partial understanding of these applications of physics. | (Partially) correct mathematical solution to the given problems.<br><br>AND / OR<br><br>Reasonably thorough understanding of these applications of physics. | Correct mathematical solution to the given problems.<br><br>AND<br><br>Thorough understanding of these applications of physics. |
| (b) | The reading will be zero. Across each cell the voltage rise (1 volt) must be equal to the voltage drop ($I$ . $R$), so the total voltage change across each circuit element is zero. | | | |
| (c)(i) | The circuit is symmetrical. Equal sized currents must flow along the identical paths AB and AD. This means that the voltage drops across resistors AB and AD will be the same and so the potential at B and D will be the same. | | | |
| (c)(ii) | DO and BO do not have any current through them so do not contribute to the resistance.<br>This leaves 3 parallel branches, each of resistance $2r$. The total will be $2r$ / 3 Ω. | | | |
| (d) | $\frac{kqq}{R^2} = \frac{k4qq}{(L-R)^2}$<br>$(L-R)^2 = 4R^2$<br>$L^2 - 2L^2 - 3R^2 = 0$<br>$(L-3R)(L+R) = 0$<br>$L = 3R$ so $R = \frac{L}{3}$ | | | |

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|---|---|---|---|---|
| SIX<br>(a) | Force on an object mass $m$ due to gravity = $\frac{GMm}{R^2}$<br>$M = \frac{4}{3}\pi R^3 \rho$ (where $\rho$ is the density of the planet, assumed constant)<br>$F = \frac{4}{3}\pi\rho G m R$<br>The force of gravity is in the opposite direction to the displacement R measured from the centre of the planet.<br>$F = -\frac{4}{3}\pi\rho G m R$<br>$F = ma$<br>$a = -\frac{4}{3}\pi\rho G R$<br>Acceleration is proportional to – $R$ ( since the other terms are constants).<br>This is the condition for SHM. | Thorough understanding of these applications of physics.<br><br>OR<br><br>Partially correct mathematical solution to the given problems.<br><br>AND/OR<br><br>Partial understanding of these applications of physics. | (Partially) correct mathematical solution to the given problems.<br><br>AND/OR<br><br>Reasonably thorough understanding of these applications of physics. | Correct mathematical solution to the given problems.<br><br>AND<br><br>Thorough understanding of these applications of physics. |
| (b) | $a_{max} = \omega^2 A$ ( This expression means that a candidate can work out this answer without having managed part (a) by assuming $a_{max} = 9.81$ )<br>$T = \frac{2\pi}{\omega} = \frac{2\pi}{\sqrt{\frac{4}{3}\pi \times 5.5 \times 10^3 \times 6.67 \times 10^{-11}}}$<br>$T = 5.069 \times 10^3$ s | | | |
| (c) | Work out the period of the satellite using $\frac{4\pi^2 R}{T^2} = \frac{GM_E}{R^2}$ and spot that the two periods are the same; or recognise that the LEO represents the reference circle for the SHM. | | | |
| (d) | The falling object would be subject to a Coriolis force, which would make the object collide with the side of the tube continuously as it fell. The object would start with a tangential velocity at right angles to the radius it is falling along. Deeper parts of the hole will not have as great a tangential velocity, and so the object will be going faster (towards the East) than the hole is going. The object will bang into the east wall of the hole – all the way down. | | | |