# Assessment Schedule 2008

# Scholarship Physics (93103)

## Evidence Statement

| Question | Evidence | 1-4 marks | 5-6 marks | 7-8 marks |
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| 1(a) | The dark lines correspond to light that has the correct energy to excite transitions between the quantised energy levels of electrons of the atoms (or molecules) in the gas.<br><br>The light is absorbed by the gas and re-emitted (in all directions), and so there is a strong dip in the intensity of the spectrum at these energies, causing dark lines. | Shows some understanding of the underlying physics.<br><br>AND / OR<br><br>(partially) correct mathematical solution to given problem. | A reasonable understanding of the underlying physics.<br><br>AND<br><br>(partially) correct mathematical solution to given problem. | Thorough understanding of the underlying physics.<br><br>AND<br><br>Correct mathematical solution to the given problem. |
| (b) | Diffraction illustrates the wave aspect of light. Diffraction is the spreading out of a wavefront when passing through a gap or obstacle. The wavefront acts a series of secondary sources. A stream of particles passing through a gap would not spread out in this manner.<br><br>Light striking a metal surface can lead to emission of an electron. That electron's maximum energy is directly related to the frequency of the incident light and not the intensity. | | | |
| (c) | Approximately 90% of photons emitted by a hot filament light bulb are in the infrared, so 10 W of visible photons are being emitted. A typical wavelength for visible photons is 500 nm. Therefore, energy of photon,<br>$E=\frac{hc}{\lambda}=\frac{6.63\times10^{-34}\text{ J s}\times3.00\times10^{8}\text{ m s}^{-1}}{5.00\times10^{-7}\text{ m}}=3.98\times10^{-19}\text{ J}$<br>The number of photons emitted<br>$=\frac{10\text{ J s}^{-1}}{3.98\times10^{-19}\text{ J}}=0.25\times10^{20}$ photons per second, ie<br><br>approximately $10^{19}$ photons per second | | | |
| (d) | To achieve fusion, the two nuclei would have to just touch (ie approach within at least one nuclear radius), ie $10^{-15}$ m. For two deuterium nuclei that were originally well apart, the kinetic energy needed to make them approach within one nuclear radius will be very high due to electrostatic repulsion. At room temperature very few nuclei would have the required kinetic energy, making fusion unlikely. | | | |

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| 2(a)(i) | If the system is stable the sum of turning forces on the system will be zero.<br>Taking moments about O, there are only two torques, $M$ g $a$ (clockwise) and $m$ g $b$ ( anticlockwise). These two must be equal if the system is to be stable.<br>Taking external torques around the point of balance,<br>$Mga - mgb = 0 \Rightarrow Ma = m\text{b} \Rightarrow M/m = b/a$ | Partially correct mathematical solution to the given problems.<br><br>AND / OR<br><br>Partial understanding of this application of physics. | (Partially) correct mathematical solution to the given problems.<br><br>AND / OR<br><br>Reasonably thorough understanding of this application of physics. | Correct mathematical solution to the given problems.<br><br>AND<br><br>Thorough understanding of this application of physics. |
| (ii) | $\cos\theta = \frac{b}{L}$ and $\cos\theta = \frac{(c-a)}{(L+d)}$<br>Therefore, $\frac{b}{L} = \frac{(c-a)}{(L+d)}$<br>$\Rightarrow \frac{\left(\frac{aM}{m}\right)}{L} = \frac{(c-a)}{(L+d)} \quad \left[\text{from } \frac{M}{m} = \frac{b}{a}\right]$<br>$\Rightarrow \frac{a(L+d)M}{mL} = c-a$<br>$\Rightarrow c = \frac{a(mL+(L+d)M)}{mL}$<br>$\Rightarrow c = \left(\frac{\cos\theta}{M}\right)(mL+(L+d)M) \quad \left[\text{from } \cos\theta = \frac{b}{L} = \frac{aM}{mL}\right]$<br>$\Rightarrow \cos\theta = \frac{Mc}{(mL+(L+d)M)}$<br>$\Rightarrow \cos\theta = \frac{Mc}{(m+M)L+Md}$ | | | |
| (b) | If $M$ is too large and / or $c$ is too big, then $\cos\theta$ will be greater than 1. This cannot happen – the system will rotate so that the bottle hits the bench. | | | |
| (c) | $\cos\theta$ will drop as $L$ is in the denominator and therefore $\theta$ will increase.<br><br>Assuming constant mass as L increases, b increases so the anticlockwise torque increases. This is unstable; to return to equilibrium conditions $\theta$ must increase. | | | |
| (d) | When the wine is removed, $M$ will decrease, so the clockwise torque will decrease. Moving the neck of the bottle to the right will increase the torque again by increasing the distance from the centre of mass over which the weight force acts. | | | |

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| 3(a) | Change in height = AB $\cos\theta = h\cos\theta$<br>GPE = $mg$ × change in height = $mgh\cos\theta$ | Thorough understanding of this application of physics.<br><br>OR<br><br>Partially correct mathematical solution to the given problems.<br><br>AND / OR<br><br>Partial understanding of this application of physics. | (Partially) correct mathematical solution to the given problems.<br><br>AND / OR<br><br>Reasonably thorough understanding of this application of physics. | Correct mathematical solution to the given problems.<br><br>AND<br><br>Thorough understanding of this application of physics. |
| (b)(i) | Her angular momentum ($I\omega$) is unchanged because no external torques act but her moment of inertia ( $I \propto mr^2$ ) decreases because her mass moves nearer the centre of the angular motion. If $I$ decreases, the angular velocity $\omega$ must increase to keep the angular momentum constant | | | |
| (b)(ii) | $\Delta E_K = E_2 - E_1 = \frac{1}{2}I_2\omega_2^2 - \frac{1}{2}I_1\omega_1^2$<br>(from b) $\omega_2 = \frac{I_1\omega_1}{I_2}$<br>so $\Delta E_K = \frac{1}{2}\omega_1^2\left(\frac{I_1^2}{I_2} - I_1\right)$<br>$\Delta E_K = \left(\frac{I_1^2 - I_1 I_2}{2I_2}\right)\omega_1^2$<br>Maximum gain in KE is at the bottom of the swing, when $\omega_1$ is at its maximum value. | | | |
| (c) | The increase in gravitational potential energy at the bottom of the swing = $mgh$<br>At the bottom of the swing, the increase in rotational kinetic energy = $\frac{1}{2} I_2\omega_2^2 - \frac{1}{2} I_1\omega_1^2$<br>But $I_1\omega_1 = I_2\omega_2 \Rightarrow \omega_2 = \frac{I_1\omega_1}{I_2}$<br>Therefore, incr. in rot. energy $= \frac{1}{2}I_2\omega_2^2 - \frac{1}{2}I_1\omega_1^2$<br>$= \frac{1}{2}I_2\left(\frac{I_1\omega_1}{I_2}\right)^2 - \frac{1}{2}I_1\omega_1^2 = \frac{1}{2}I_1\omega_1^2\left(\frac{I_1}{I_2} - 1\right)$<br>$= \frac{I_1^2\omega_1^2 - I_1 I_2\omega_1^2}{2I_2}$<br>The total change in energy at the bottom is the change in rotational energy plus change in potential energy<br>$= \frac{I_1^2\omega_1^2 - I_1 I_2\omega_1^2}{2I_2} + mgh$<br>And the change in energy at the top is clearly $-mgh\cos\alpha$<br>Therefore net change of energy<br>$= \left(\frac{I_1^2 - I_1 I_2}{2I_2}\right)\omega_1^2 + mgh - mgh\cos\alpha$ | | | |

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| (d) | GPE lost = Rotational KE gained<br>$mgh = \frac{1}{2} I_1 \omega_1^2$<br>$h = 3 - 3\cos\theta \quad I_1 = mr^2 \ (r = 3\,\text{m})$<br>$so\ \omega_1^2 = \frac{(2 \times 9.80 \times (3 - 3\cos\theta))}{9}$<br>After the stand up<br>$\omega_2 = \frac{I_1 \omega_1}{I_2}$<br>$mgh_{\text{new}} = \frac{1}{2} I_2 \omega_2^2$<br>$50 \times 9.80 \times h_{\text{new}} = \frac{1}{2} \frac{(50 \times 3^2)^2 \omega_1^2}{50 \times 2.6^2}$<br>$h_{\text{new}} = \frac{9(3 - 3\cos 30°)}{2.6^2} = 0.535106\ \text{m}$<br>$\cos\theta_{\text{new}} = \frac{2.6 - 0.535106}{2.6}$<br>$\theta_{\text{new}} = 37.4°$ | Partially correct mathematical analysis of given problems<br><br>And/or<br><br>Partial discussion of the underlying physics of the LCR resonant circuit<br><br>OR<br><br>Correct mathematical analysis of given problems | (Partially) correct mathematical analysis of given problems<br><br>And<br><br>Reasonably thorough discussion of the underlying physics of the LCR resonant circuit | Correct mathematical analysis of given problems<br><br>And<br><br>Thorough discussion of the underlying physics of the LCR resonant circuit |

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| 4(a)(i) | That the Doppler effect is symmetrical - the gain in frequency heard by the observer B will be the same as the reduction in frequency heard by observer A | Shows some understanding of the underlying physics.<br><br>AND / OR<br><br>(partially) correct mathematical solution to given problem. | A reasonable understanding of the underlying physics.<br><br>AND<br><br>(partially) correct mathematical solution to given problem. | Thorough understanding of the underlying physics.<br><br>AND<br><br>Correct mathematical solution to the given problem. |
| (ii) | For A, $f = \frac{f_0 v}{\left(v + v_s\right)}$ = 1457/1417 by substitution | | | |
| (iii) | The Doppler effect is not symmetrical. If the source travels as fast or faster than the wave speed of the emitted sound, then a forward observer will hear nothing until the source actually reaches the observer. And the sound heard will have "infinite" frequency - it will be a "sonic boom". Waves travelling backwards will still eventually reach the rear observer, just with a reduced frequency - that frequency will never drop to zero, no matter how fast the source moves. | | | |
| (b) | All true except the last point, "it is this that gives the orange-red colour." The Earth does spin to the East and so it is to the East that we see the morning Sun. In both the morning and evening the Sun is low on the horizon and so the Sun appears to be approaching/receding faster than at other times of the day when it is overhead. The light is red-shifted in the evening (because the Sun appears to be moving away, but it would be equally blue shifted in the morning by the same argument. In fact, the velocity (approx 450 $ms^{-1}$) of the observer, created by the spinning earth is too slow to make a measurable difference.<br>(Teaching note: The colour of the sunset is caused by shorter wavelength (green-blue) light waves being scattered by atmospheric particles, leaving just the red-orange in the direct line of sight.) | | | |

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| 5(a)(i) | The centre of mass will continue in the same direction regardless of the explosion. There is no external force applied to alter the motion of the centre of mass. | Shows some understanding of at least one of the following aspects of the physics of the situation outlined – for example centre of mass, momentum, acceleration, energy considerations. | Shows clear understanding of some relevant aspects of the physics of the situation outlined—for example centre of mass, momentum, acceleration, energy considerations. | Shows insight in relation to all relevant aspects of the physics of the situation outlined. |
| (ii) | Assume a spherical asteroid. Take $r = 0.725 \times 10^6$ m (half the "diameter" of Texas).Mass of the asteroid = $4/3\ \pi\ r^3\ \rho$<br>$= 4.8 \times 10^{21}$ kg<br>Mass of each half $= 2.4 \times 10^{21}$ kg<br>Assume all of the bomb energy is converted into KE of the lumps in the $y$ direction – velocity (v) in the y direction given by $\frac{1}{2}mv^2 = E$ (assume half the $E_k$ goes to each lump)<br>$0.5 \times 2.4 \times 10^{21}\ v^2 = 2.5 \times 10^{18}$<br>$v = 0.046$ m s$^{-1}$<br>In 4 hours, $4 \times 3600$ s, the $y$ distance moving by each half will be 657 m (700 m)<br>The distance needed to be moved is much larger than this so we are doomed! | | | |
| (iii) | Assume that both halves are spherical<br>The radius of each spherical lump is given by<br>$r^3 = \frac{3M}{4\partial\rho}$<br>$= \frac{3\times2.4\times10^{21}}{4\partial\times3000}$<br>$r = 0.58\times10^6$ m<br>Force of gravitational attraction between the two lumps<br>$F = \frac{GmM}{r^2}$<br>$F = \frac{6.67\times10^{-11}\times2.4\times10^{21}\times2.4\times10^{21}}{1.33\times10^{12}}$<br>$F = 2.9\times10^{20}$<br>This force will cause the two lumps to accelerate towards each other<br>$a = \frac{F}{m}$<br>$a = \frac{2.9\times10^{20}}{2.4\times10^{21}}$<br>$a = 0.12\,\text{ms}^{-2}$<br>This is 12 cm s$^{-2}$. The maximum speed of separation from the blast is only<br>4.6 cm s$^{-1}$. In other words the self gravitation would almost immediately overwhelm the force from the blast and bring the asteroid back together. The asteroid might "heave" but it would not split apart. | | | |

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| 6(a)(i) | Kirchhoff's Potential Difference Law is a statement of the conservation of energy - in any closed loop the energy lost by circulating charges must equal the energy gained, as they complete the loop with same energy level that they started with.<br>Kirchhoff's Current Law is a statement of the conservation of charge. Since there is no way for charge to be accumulated at a junction, the amount of charge leaving must equal the amount of charge arriving. | Partially correct mathematical solution to the given problems.<br><br>AND / OR<br><br>Partial discussion of the underlying physics of this application. | (Partially) correct mathematical solution to the given problems.<br><br>AND<br><br>Reasonably thorough discussion of the underlying physics of this application. | Thorough discussion of the underlying physics of this application.<br><br>AND<br><br>Correct mathematical solution to the given problems. |
| (a)(ii) | Use loop law to calculate current in the 4 ohm resistor<br>$24 = 1 \times 12 + 4 \times i_1$ gives $i_1 = 3$ A<br>and current in 8 ohm = 2 A. | | | |
| (b)(i) | The voltage across both resistors will start at 12 V when the switch is closed.<br>Since the 1μF capacitor will charge quickly ($\tau = 1/1000$ s), the voltage across the 1 kΩ resistor will fall and become effectively zero after 5/1000s.<br>The mF capacitor with $\tau = 10$s will charge slowly and so the voltage across the 10kΩ resistor will fall, but take 50 s to reach effective zero. | | | |
| (b)(ii) | After 10 s<br>The 1 μF is charged to 12V. The 1000μF is only charged to $12 \times 0.63 = 7.56$ V. When the battery is removed the capacitor voltages will equalise with a flow of charge from the 1 μF to the 1000 μF. The voltage of the 1μF will fall and that of the 1000 μF will rise.<br><br>Initial current is given by Voltage difference / Resistance<br>It is $\frac{4.44}{11\,\text{k}} = 0.403$ mA<br><br>Total charge must remain constant so $Q_T = Q_1 + Q_{1000}$<br>$= 10^{-6} \times 12 + 10^{-3} \times 7.56$<br>$= 7.572 \times 10^{-3}$ C<br>Total capacitance = $C_1 + C_2 = 1001 \times 10^{-6}$ F<br>Final voltage of capacitors = Q / C = 7.572 / 1.001<br>= 7.56(4) V | | | |