# Assessment Schedule – 2014

# Scholarship Physics (93103)

## Evidence Statement

| Q | Evidence | 1–4 marks | 5–6 marks | 7–8 marks |
|---|---|---|---|---|
| ONE (a) | $E = \text{h}f$<br>14.0 keV = $14.0 \times 10^3 \times 1.6 \times 10^{-19} = 2.24 \times 10^{-15}$ J<br>$f = \frac{E}{\text{h}} = \frac{2.24\times10^{-15}\text{ J}}{6.63\times10^{-34}\text{ J s}} = 3.38\times10^{18}\text{ Hz}$ | 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) | $\Delta E = \frac{Eg\Delta x}{\text{c}^2}$<br>So, $\text{h}(f + \Delta f) = E + \Delta E$<br>So, $\frac{\Delta f}{f} = \frac{\frac{\Delta E}{\text{h}}}{\frac{E}{\text{h}}} = \frac{\Delta E}{E}$<br>$= \frac{g\Delta x}{\text{c}^2} = \frac{9.81\times 22.5}{(3\times10^8)^2}$<br>$= 2.45\times10^{-15}$ | | | |
| (c) | The frequency of the incident gamma rays can be reduced by the movement of the source or detector away from each other. Such movement apart will result in an increase in the wavelength of the waves which, because the wave velocity is constant, will cause the frequency to decrease the necessary amount. | | | |
| (d) | $f' = f\left(1+\frac{v_s}{2v_w}\right)^2$<br>$\Delta f = f' - f = f\left(1+\frac{v_s}{2v_w}\right)^2 - f$<br>$= f\left(1+\frac{v_s}{v_w}+\left(\frac{v_s}{2v_w}\right)^2 - 1\right)$<br>$= f\left(\frac{v_s}{v_w}+\left(\frac{v_s}{2v_w}\right)^2\right)$<br>$= f\left(\frac{v_s}{v_w}\right)$, to first order (ie if $\frac{v_s}{v_w} << 1$)<br><br>Given that $v_w = 3 \times 10^8$ m s$^{-1}$, this is a good assumption.<br>$v_s$ would be at most ~100 m s$^{-1}$ in lab situation. | | | |

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| TWO (a) | At the top of the jump, Emma's centre of mass is 1 m above the platform. At the bottom of the jump, Emma's centre of mass is 1 m above the river. So Emma's centre of mass moves 25 m, from the platform to the bottom of the jump.<br>Loss of gravitational potential energy is $mgh$.<br>Extension of bungy spring is $x = (25 - 2) - L$.<br>Gain in potential energy of the spring is $0.5kx^2 = 0.5k(23 - L)^2$<br>Therefore, gravitational potential energy = spring potential energy so $mgh = 0.5\text{k}(23 - L)^2$ | 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) | At equilibrium, downward force of gravity = upward force of spring $m\text{g} = \text{k}x = \text{k}(25 - 10 - L)$ ie, $m\text{g} = \text{k}(15 - L)$ | | | |
| (c) | From Two (a) and Two (b), equating expressions for $mgh$<br>$0.5\text{k}(23 - L)^2 = \text{k}(15 - L)h$ The "k"s cancel, and $h$ is 25 m.<br>So $0.5\,(23 - L)^2 = (15 - L)25$ therefore $(23 - L)^2 = (15 - L)50$<br>$529 + L^2 - 46L = 750 - 50L$<br>$L^2 + 4L - 221 = 0$<br>Solving this and taking the positive root gives $L = 13$ m. | | | |
| (d)(i) | Maximum speed occurs at the point that Emma feels zero acceleration (before this the acceleration is downwards, and after this the acceleration is upwards, which slows the velocity). Zero acceleration when $m\text{g} = \text{k}x$<br>We know that $\frac{m\text{g}}{\text{k}} = 2$.<br>Therefore, zero acceleration at $x = 2$.<br>Loss of potential energy at $x = 2$ is $m\text{g}(L + 2 + 2)$<br>$= m\text{g}(L + 4)$<br>Gain of spring potential energy at $x = 2$ is $0.5\text{k}2^2 = 2\text{k}$<br>Therefore, KE $= m\text{g}(13 + 4) - 2\text{k} = 17\,m\text{g} - 2\text{k}$<br>$0.5\,mv^2 = 17\,m\text{g} - 2\text{k}$<br>$v^2 = 34\text{g} - 4\frac{\text{k}}{m} = 34\text{g} - 2\text{g}$ (from Two (b)) $= 32\text{g} = 32(9.81)$<br>$= 313.92$ therefore, $v = 17.7\text{ m s}^{-1}$ | | | |
| (ii) | Maximum acceleration downwards is $g$. But we know that the bungy counteracts this and actually turns around the motion.<br>Maximum acceleration due to bungy is $\frac{\text{k}x}{m}$ and is maximum when $x$ is a maximum. Maximum value of $x$ is 10 m, and $\frac{\text{k}}{m} = \frac{g}{2}$ (from Two (b)). So maximum acceleration due to bungy is 5g ($49.05\text{ m s}^{-2}$). Subtract the acceleration due to gravity, to get maximum of 4 g ($39.24\text{ m s}^{-2}$). | | | |
| (e) | If force F is applied to the bungy, the change in length of the whole bungy will be $x$. If we imagine the bungy to be made of two parts, each part will extend by $\frac{x}{2}$ .Since the force is the same, the spring constant has doubled. | | | |

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| THREE (a) | Momentum of projectile = 0.01 kg × 60 m $s^{-1}$<br>Momentum of cube plus projectile = 0.81 kg × $v$ m $s^{-1}$<br><br>Equating them, $0.01 \times 60 = 0.81v$<br>$v = \dfrac{0.6}{0.81} = 0.741$ m $s^{-1}$<br>ie $v = \dfrac{m_{\text{projectile}} V_{\text{projectile}}}{m_{\text{projectile}} + M_{\text{cube}}}$ | 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) | Angular momentum initially = $mvr$<br>$= m_{\text{projectile}} V_{\text{projectile}}\, d$<br>This is the angular momentum of the cube plus projectile = $I\omega + m_{\text{projectile}} r^2 \omega$<br>$I\omega + m_{\text{projectile}} r^2 \omega = m_{\text{projectile}} V_{\text{projectile}} d$<br>$\omega = \dfrac{m_{\text{projectile}} V_{\text{projectile}} d}{I + m_{\text{projectile}} r^2}$ | | | |
| (c) | Initial $KE = 0.5 m_{\text{projectile}} V_{\text{projectile}}^2$<br>Final $KE = \dfrac{0.5\left(m_{\text{projectile}} + M_{\text{cube}}\right)\left(m_{\text{projectile}} V_{\text{projectile}}\right)^2}{\left(m_{\text{projectile}} + M_{\text{cube}}\right)^2}$<br><br>$\dfrac{\text{Final } KE}{\text{Initial } KE} = \dfrac{0.5\left(m_{\text{projectile}} + M_{\text{cube}}\right)\left(m_{\text{projectile}} V_{\text{projectile}}\right)^2}{\left(m_{\text{projectile}} + M_{\text{cube}}\right)^2} \Big/ 0.5 m_{\text{projectile}} V_{\text{projectile}}^2$<br>$= \dfrac{m_{\text{projectile}}}{\left(m_{\text{projectile}} + M_{\text{cube}}\right)}$ | | | |
| (d) | Some energy has gone to rotational $KE$, $0.5 I' \omega^2$, where $I'$ = moment of inertia of cube plus projectile. The remainder has been lost as heat and in deforming the blocks. | | | |
| (e) | The shape will have its centre of mass move with approximately twice the velocity of the original cube (because the mass is half as much). The moment of inertia is significantly reduced and so the final angular velocity must also increase (L is slightly reduced but I is reduced significantly leading to an increase in angular velocity). | | | |

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| FOUR (a) | The work-energy theorem states that work done = $\Delta E_K$. Since no change has occurred to the velocity and therefore the kinetic energy, no work has been done on the sheets. | 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) | $N_A(d+x) = N_B(d-x) = (mg - N_A)(d-x)$<br>*Since* $mg = N_A + N_B$<br><br>Therefore, $N_A(d + x + d - x) = mg(d-x)$<br>$N_A = \dfrac{mg(d-x)}{2d}$ | | | |
| (c) | $F_A = \dfrac{\mu mg(d-x)}{2d}$<br>$F_B = \dfrac{\mu mg(d+x)}{2d}$<br>These two frictional forces are oppositely directed, and so<br>$F_{net} = \dfrac{\mu mg 2x}{2d} = \dfrac{\mu mgx}{d}$<br><br>However, if the sheet moves to the right (positive $x$), roller B will move it to the left, and vice versa for A.<br>So $F_{net} = -\dfrac{\mu mgx}{d}$<br>This is simple harmonic motion as the force is proportional to the displacement but oppositely directed. | | | |
| (d)(i) | $\omega^2 = \dfrac{\mu g}{d}$ (from the SHM equation above)<br>$\omega = \dfrac{2\pi}{T}$<br>$T^2 = \dfrac{d4\pi^2}{\mu g}$<br>Substituting shows that $T = 2.46$ s | | | |
| (ii) | Friction = $\mu N = 0.2N = 0.2Mg$ ($M$ = mass of the object)<br>Max acceleration without slipping is $0.2g$<br>Max acceleration = $A\omega^2$<br>$A = \dfrac{0.2g}{\omega^2} = 0.300$ m (since $\omega^2 = \dfrac{\mu g}{d}$ ) | | | |

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| FIVE (a)(i) | At the steady state condition, no current will flow in the branch with the capacitor present. Therefore the current in the 3kΩ resistor will be zero.<br>The rest of the circuit becomes a simple series circuit with resistance 27 kΩ and voltage 9 V; therefore the current is<br>$I = \frac{9.00}{27\times10^{3}} = 3.33\times10^{-4}$ A | 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) | $Q = CV$<br>$Q = 10.0\times10^{-6}\times V$<br>$V = IR$ ($V$ across 15 kΩ = $V$ across capacitor)<br>$V = 3.33\times10^{-4}\times15.0\times10^{3} = 5.00$ V<br>$Q = 10.0\times10^{-6}\times5.00 = 50.0$ μC | | | |
| (iii) | On opening the switch, the circuit becomes a simple series circuit, with a source voltage of 5.00 V and a resistance of 18.0 kΩ.<br>$I = \frac{5.00}{18\times10^{3}} = 2.78\times10^{-4}$ A | | | |
| (b) | The field lines at the edge of the capacitor are not vertical. They are arced and so have a component acting parallel to the capacitor plate surface. This component will attract the polarised charges of the dielectric (in the same way as charged objects can "pick up" small objects). | | | |
| (c) | $\Delta E\text{ (capacitance)} = \frac{1}{2}\frac{Q^2}{C_i} - \frac{1}{2}\frac{Q^2}{C_F}$<br>$C_F = \varepsilon_r C_I$ by definition<br>$\Delta E = \frac{1}{2}\frac{Q^2(\varepsilon_r - 1)}{\varepsilon_r C_i}$<br>$\Delta E = \frac{1}{2}mv^2 = \frac{1}{2}\frac{Q^2(\varepsilon_r - 1)}{\varepsilon_r C_i}$<br>$v = \sqrt{\frac{Q^2(\varepsilon_r - 1)}{m\varepsilon_r C_i}}$ | | | |
| (d) | Capacitors store energy. They do this by way of charge separation (increasing the electric potential energy of the charges). The total unbalanced charge of any capacitor is always zero. | | | |