Assessment Schedule – 2018

Physics: Demonstrate understanding of mechanical systems (91524)

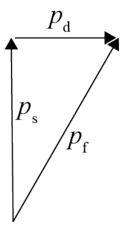
Evidence Statement

NØ	N1	N2	A3	A4	M5	M6	E7	E8
0	1A	2A or 1M	3A or 1A +1M or 1E-	4 A or 2A + M or 2M or 1A+1E-	1A + 2M or 1M+1E- or 3A +1M or 2A + 1E-	2A + 2M or 3M or 3A + 1E- or 1A +1M + 1E-	2M+1E- or 2A +1M + 1E- or A + 2M + 1E-	A + 2M +E

Other combinations are also possible using a=1, m=2 and e=3. However, for M5 and M6, at least one Merit question needs to be correct (maximum 6). For E7 or E8, at least one Excellence needs to be correct (maximum 8). **Note: E- and E only applies to the E7 and E8 decision.**

Q	Evidence	Achievement	Merit	Excellence
ONE (a)	$F=\frac{GMm}{r^2}$ $F=\frac{6.67\times10^{-11}\times5.97\times10^{24}\times150.0}{\left(6.37\times10^{6}+5.00\times10^{5}\right)^2}=1265.5\text{ N}$ $=1270\text{ N (3 sf)}$	• Correct WORKING (Note, NOT answer as this is a SHOW question).		
(b)	$\frac{GMm}{r^2}=\frac{mv^2}{r}$ $v=\sqrt{\frac{GM}{r}}=7.613\times10^{3}\text{ m s}^{-1}=7.61\times10^{3}\text{ m s}^{-1}\text{ (3 sf)}$ Please accept the following answer due to the error in the formula v = 3.82×10^{-8} m s^{-1} (Using m as the mass of the satellite.)	• Equates gravitational force and centripetal force. (Accept $F_c = F_g$) OR Calculates the velocity using the given formula in the question.	• Both achieved points.	

(c)(i)	$m_1 x = m_2(1.08\times10^4 - x)$ $1.50\times10^2 \times x = 20\times1.08\times10^4 - 20x$ $170x = 20\times1.08\times10^4$ $x = \dfrac{20\times1.08\times10^4}{170} = 1270\text{ m}$ OR $x_{\text{com}} = \dfrac{m_1x_1 - m_2x_2}{m_1+m_2}$ $x_{\text{com}} = \dfrac{1.50\times10^2\times0+20\times1.08\times10^4}{20+150} = 1270\text{ m}$	• Correct method with incorrect calculation (could be a substitution error OR measured from the wrong end) OR	• Correct Centre of Mass calculation AND States that the motion of the centre of mass will continue at constant velocity because there are no unbalanced horizontal force. (Ignore the need for the word "horizontal".)	
(ii)	Centre of mass will continue to move with uniform speed and direction since there are no unbalanced forces **in the horizontal direction.** **Accept 'Closed system' or 'no external forces' in the explanation)**	States that the velocity of the centre of mass will be constant. (ignore the need for the word "horizontal")		

(d)	 $v=\sqrt{\frac{GM}{r}}=7.613\times10^3\ \text{m s}^{-1}$ $p_s=mv=150\times7.61\times10^3$ $=1.142\times10^6\ \text{kg m s}^{-1}$ $p_d=mv=20.0\times7.61\times10^3$ $=1.523\times10^5\ \text{kg m s}^{-1}$ $p_f^{\,2}=p_d^{\,2}+p_s^{\,2}$ $p_f^{\,2}=(1.142\times10^5\ \text{kg m s}^{-1})^2+(1.523\times10^5\ \text{kg m s}^{-1})^2$ $p_f=\sqrt{1.32735\times10^{12}}\ \text{kg m s}^{-1}$ $=1.152\times10^6\ \text{kg m s}^{-1}$ $v_f=\frac{p_f}{\text{mass}}=\frac{1.152\times10^6}{170}=6776\ \text{m s}^{-1}=6780\ \text{m s}^{-1}$ Direction $\tan^{-1}\left(\frac{1.523\times10^5\ \text{kg m s}^{-1}}{1.142\times10^6\ \text{kg m s}^{-1}}\right)=7.60°$ Note: Look for an angle of 82.4°. This is the complement of 7.6°.	• Calculates either of the initial momentum values correctly OR Calculates final momentum correctly using wrongly calculated initial values of momentum (no direction required) OR Calculates the angle of the new momentum correctly (Allow follow on error for velocity from Q1b for all of the above.)	• Correct magnitude of final momentum. (Allow follow on error for velocity from Q1b.)	• Calculates final velocity including direction. (E) • Calculates final velocity including direction with follow on error from Q1b. (E) • Calculates the final SPEED (no direction). (E–) • Calculates the final SPEED with a follow on error from 1b (no direction). (E–) (This can be checked quickly using final velocity is 89% of the orbital velocity that the candidate has used.)

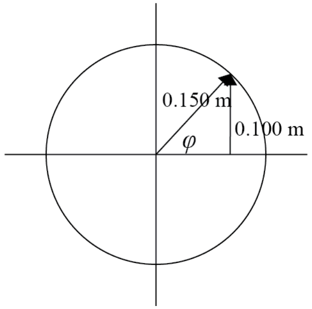
	Accept: $v=\sqrt{\frac{GM}{r}}=3.82\times10^{-8}\text{ m s}^{-1}$ $p_{\text{s}}=mv=150\times3.82\times10^{-8}$ $=5.73\times10^{-6}\text{ kg m s}^{-1}$ $p_{\text{d}}=mv=20.0\times3.82\times10^{-8}$ $=7.64\times10^{-7}\text{ kg m s}^{-1}$ ${p_{\text{f}}}^2={p_{\text{d}}}^2+{p_{\text{s}}}^2$ ${p_{\text{f}}}^2=(5.73\times10^{-6}\text{ kg m s}^{-1})^2+(7.64\times10^{-7}\text{ kg m s}^{-1})^2$ $p_{\text{f}}=\sqrt{3.34\times10^{-11}}\text{ kg m s}^{-1}$ $=5.77\times10^{-6}\text{ kg m s}^{-1}$ $v_{\text{f}}=\frac{p_{\text{f}}}{\text{mass}}=3.40\times10^{6}\text{ m s}^{-1}$ Direction $\tan^{-1}\left(\frac{1.523\times10^{5}\text{ kg m s}^{-1}}{1.142\times10^{6}\text{ kg m s}^{-1}}\right)=7.60°$			

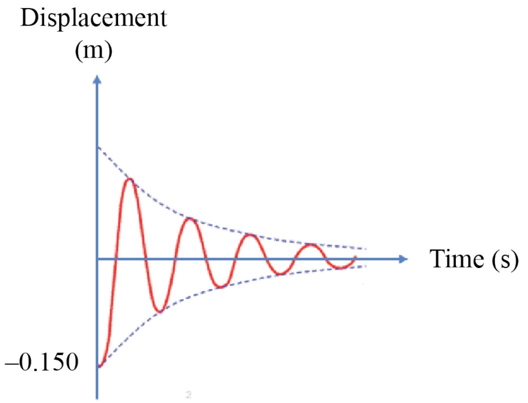
Q	Evidence	Achievement	Merit	Excellence
TWO (a)	The period of rotation of the satellite must be the same as the period of the orbit. $T = 101 \text{ mins} \times 60 = 6060 \text{ s}$ $\omega = \frac{2\pi}{T} = 1.0368 \times 10^{-3} \text{ rad s}^{-1}$ $= 1.04 \times 10^{-3} \text{ rad s}^{-1} \text{ (3 sf)}$	• Some evidence of working or reasoning leading to the correct answer. (This is a SHOW question)		
(b)	Pure rotational acceleration requires the torques to be additive but the forces to cancel. For this to occur there needs to be two thrusters whose forces cancel by acting in opposite directions but whose torques add. One thruster only would result in an unbalanced force and change the motion of the centre of mass – taking the satellite off course.	• If there were only one thruster, it would deliver an unbalanced force. OR Pure rotation requires torque from equal and opposite forces.	• Both.	

(c)	$\omega_f = \omega_i + \alpha\Delta t$ $\omega_i = 0$ $\alpha = \frac{\omega_f}{\Delta t} = \frac{1.0368\times10^{-3}}{6.48\times10^{-3}} = 0.160\text{ rad s}^{-2}$ (same answer if rounded value used) $\tau = F \times d$ There are two torques in the same direction. Total torque $\tau = 2\times5.00\times0.80 = 8.00\text{ N m}$ $\tau = I\alpha$ $I = \frac{\tau}{\alpha} = \frac{8.00}{0.160}$ $I = 50.0\text{ kg m}^2$ OR $\Delta p = F\Delta t$ $\Delta p = 5\times6.48\times10^{-3} = 0.0324\text{ N s}$ for each thruster So total $\Delta p = 0.0648\text{ N s}$ $\Delta L = \Delta p\cdot r$ $= 0.0648\times0.8$ $= 0.05184\text{ kg m}^2\text{ s}^{-1}$ $L = I\omega$ so $I = \frac{L}{\omega}$ $I = \frac{0.05184}{0.00104}$ $I = 49.9$ or 50 kg m^2	• Correctly calculates angular acceleration $= 0.160\text{ rad s}^{-2}$ OR Total torque = 8.00 N m OR Accept correct rotation calculation with incorrect torque of 16 Nm – used diameter rather than radius. OR Correctly calculates the total impulse (0.0648 N s or kgm s^{-1}) OR Correctly calculates the total change of angular momentum (0.05184 kg $\text{m}^2\text{ s}^{-1}$).	• Correct answer supported by working.	

(d)	$I=\frac{1}{2}mr^2$ $=\frac{1}{2}\times 5.00\times 0.200^2=0.100\text{ kg m}^2$ $L=I\omega$ $L=50.0\times 1.0368\times 10^{-3}$ $L=0.0518\text{ kg m}^2\text{ rad s}^{-1}$ (if rounded value used: 0.520) $L_{\text{satellite}}=L_{\text{wheel}}$ $I_{\text{satellite}}\omega_{\text{satellite}}=L_{\text{wheel}}\omega_{\text{wheel}}$ $\omega=\frac{L_{\text{satellite}}}{I_{\text{wheel}}}$ $=\frac{0.0520}{0.100}=0.518\text{ rad s}^{-1}$ These calculations depend on the fact that there are no EXTERNAL torques acting on the satellite as angular momentum is conserved.	• Calculates the rotational inertia of the flywheel/inertia-wheel. OR Calculates the angular momentum of the flywheel. OR Indicates recognition that that law of conservation of angular momentum will be involved. OR States that there are zero external torques.	• Justifies use of the law of conservation of rotational momentum by stating that there are no external torques acting on the satellite. (Note: do not accept zero external forces) OR Correct answer for angular velocity of wheel.	• Correct working with answer and states assumption that there are no external torques acting. (E) • Correct working with answer and states an incomplete assumption. (E-)

Q	Evidence	Achievement	Merit	Excellence
THREE (a)	Restoring force always acts toward the equilibrium position and is directly proportional to the displacement from the equilibrium position. OR Acceleration always acts toward the equilibrium position and is directly proportional to the displacement from the equilibrium position. OR Accept equations in the explanation e.g. ($a = -\omega^2 y$, a $\alpha - y$. $F\alpha - y$, F = $-ky$ etc.)	• Correct answer.		
(b)	$T = 2\pi\sqrt{\frac{m}{k}}$ $0.940\text{ s} = 2\pi\sqrt{\frac{80.0\text{ kg}}{k}}$ $k = 3574\text{ N m}^{-1} = 3570\text{ N m}^{-1}$ $E = \frac{1}{2}kx^2 = 0.5 \times 3574\text{ N m}^{-1} \times (0.150\text{ m})^2 = 40.2\text{ J}$	• $k = 3570\text{ N m}^{-1}$ OR $E_{spring} = 40.2$ J OR Correctly calculates Elastic potential energy with incorrect spring constant (k).	• All correct.	

(c)	Determines t using the reference circle. $\phi = \sin^{-1}\left(\frac{0.100}{0.150}\right) = 0.7297$ radians  (Accept diagram with phasor on left side of circle at same height.) OR $v_{max} = \omega A$ $= \frac{2\pi}{T} A$ $= \frac{2\pi \times 0.15}{0.94}$ $= 1.003 \text{ m s}^{-1}$ $\theta = \sin^{-1}\left(\frac{0.1}{0.15}\right) = 41.81°$ or 0.7297 rad Degrees $v = v_{max} \cos\theta$ $= 1.003 \times \cos 41.81° = 0.748 \text{ m s}^{-1}$ Radians $v = 1.003 \times \cos 0.7297 = 0.748 \text{ m s}^{-1}$ $\omega = \frac{2\pi}{T} = 6.684 \text{ rad s}^{-1}$ $\omega = \frac{\theta}{t}$ $t = \frac{0.7297 \text{ radians}}{6.684 \text{ rad s}^{-1}}$ $= 0.109 \text{ s}$ $v = A\omega \cos(\omega t)$ $= 0.15 \times 6.684 \times \cos(6.684 \times 0.109)$ $= 0.748 \text{ m s}^{-1}$	• Correct setup of reference circle for amplitude and displacement. OR Correct reference circle without arrowheads on the phasors. OR Correct selection of equation **and** substitution. OR Found the correct maximum velocity. OR Calculated the correct angle.	• Correct answer supported by working.	

(d)	Damping means a force acts in the opposing direction to the restoring force, removing energy from the system and thus reducing the amplitude of a harmonic motion. In the laboratory model, on the way upward after being released, the damping liquid provides a downward frictional force working against the upward restoring force of the spring. Once the mass reaches the top and begins to move downward, the water provides an upward, frictional force opposing the downward restoring force of gravity and the spring. The period and frequency of the motion will not be changed as these depend on the mass and the spring constant only. The damping force will transfer energy away from the system, so the amplitude will be reduced with each cycle. 	• Reasonable description of damping. OR Mentions reduced amplitude. OR Mentions constant period (and / or frequency). OR Identifies damping force as friction with the liquid. OR Reasonable attempt at a graph showing decreasing amplitude.	• Discusses THREE of the achieved aspects.	• Full description. (E) NOTE: If the graph does not start from the minimum point but has a steady period with decreasing amplitude then the maximum mark is E–. Note: Allow **E–** if there is one minor feature missing from the written answer but it is shown on the graph. For example the period is constant (shown clearly on the graph) and the amplitude decreases.

Cut Scores

Not Achieved	Achievement	Achievement with Merit	Achievement with Excellence
0 – 6	7 – 13	14 – 18	19 – 24