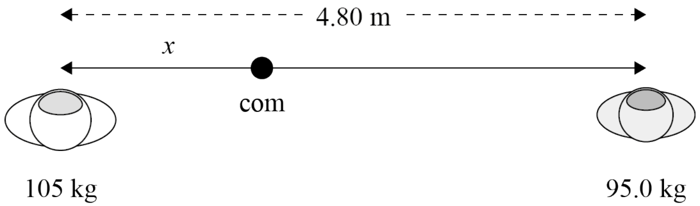
Assessment Schedule – 2017

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)	 $m_1x = m_2(4.80 - x)$ $105 \times x = 95.0 \times 4.80 - 95.0 \times x$ $200 \times x = 95.0 \times 4.80$ $x = \frac{95.0 \times 4.80}{200} = 2.28\text{ m}$ OR $x_{com} = \frac{m_1x_1 + m_2x_2}{m_1 + m_2}$ $x_{com} = \frac{105 \times 0 + 95.0 \times 4.80}{105 + 95.0}$ $x_{com} = 2.28\text{ m}$	Correct method with incorrect calculation.	Correct answer.	

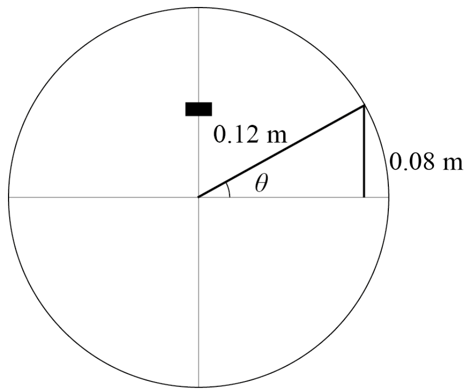
(b)	The centre of mass keeps moving at constant velocity.	Correct answer.		
(c)	$p_{\text{Sam}} = 105 \times 1.2 = 126 \text{ kg m s}^{-1}$ $p_{\text{Sylvia}} = 95 \times 1.4 = 133 \text{ kg m s}^{-1}$ $\Sigma p = \sqrt{126^2 + 133^2} = 183 \text{ kg m s}^{-1}$ $v = \frac{p}{m} = \frac{183}{200} = 0.92 \text{ m s}^{-1}$	Total momentum calculated correctly. OR Correct method with two dimensional momentum but allow follow on error for A.	Total momentum and speed calculated correctly.	

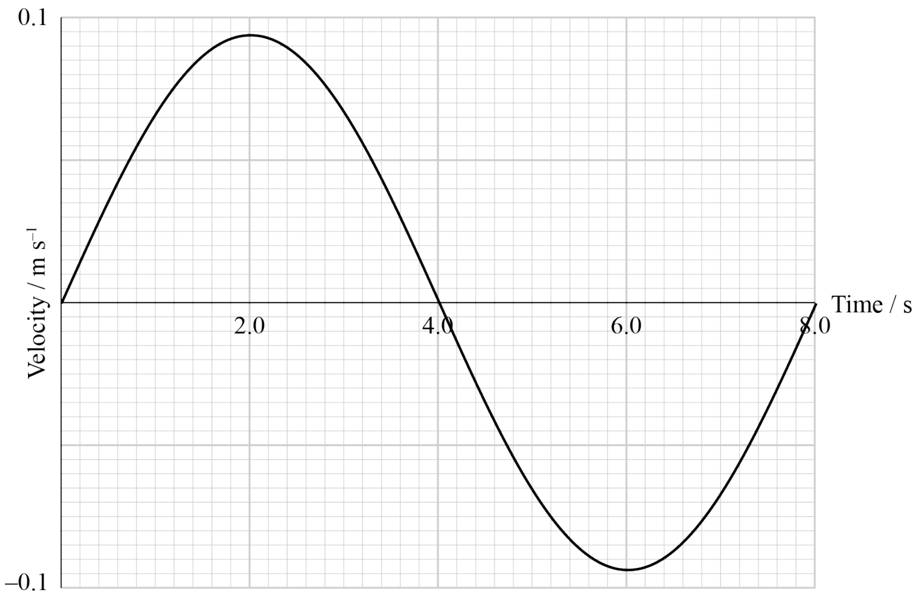
(d)(i)	$F_g = \frac{GmM}{r^2}$ $F_c = \frac{mv^2}{r}$ $v = \frac{d}{t} = \frac{2\pi r}{T}$ $\frac{GmM}{r^2} = \frac{mv^2}{r}$ $\frac{GM}{r} = \frac{v^2}{1} = \frac{4\pi^2 r^2}{T^2}$ $M = \frac{4\pi^2 r^3}{GT^2} = \frac{4\times\pi^2\times((351+5220)\times10^3)^3}{6.67\times10^{-11}\times(5.46\times10^3)^2}$ $M = 3.43\times10^{24}$ kg OR $mg = \frac{mv^2}{r}$ $g = a_c$ $a_c = \frac{v^2}{r}$ *and* $v = \frac{2\pi}{r}$ $a_c = \frac{4\pi^2 r}{t^2} = \frac{4\pi^2 r\left((351+5220)\times10^3\right)}{\left(5.46\times10^3\right)^2}$ $a_c = 7.38$ m s^{-2} and thus local $g = 7.38$ m s^{-2} $g = \frac{GM}{r^2}$ $M = \frac{gr^2}{G} = \frac{7.38\left((351+5220)\times10^3\right)^2}{6.67\times10^{-11}}$ $M = 3.43\times10^{24}$ kg	Combines F_g and F_C. OR States that gravity supplies the centripetal force. OR Uses F_g, F_c and $v = \frac{2\pi r}{T}$ to attempt to make M the subject of the formula. OR Calculates v correctly as 6410 m s^{-1}. OR Candidate recognises that this is an Energy Change situation. OR Candidate recognises that gravitational force is increasing.	Error in the calculation. e.g.: forgot to square T or π or cube r or add orbital radius while substituting. OR Algebraically makes M the subject of the formula correctly. OR calculates local $g = 7.38$ m s^{-2} OR (Two ideas linked) e.g.: As the spaceship approaches the planet, it loses gravitational potential energy and gains kinetic energy. OR (Two ideas linked) e.g.: As the spaceship approaches the planet, the distance will decrease. This will cause an increase in the size of the gravitational pull on the spaceship. OR The gravitational force on the spaceship has a component in the direction of travel; this will increase the speed.	Correct calculation and correct answer for the mass with unit. (E) OR Complete correct explanation with links. (E). Correct calculation and correct answer for the mass without unit. (E-) OR Complete explanation with links accepted with minor errors (E-) For instance, the candidate has said “speed” and not “linear speed”; both linear and rotational speeds exist here.
(ii)	As the spaceship approaches the planet, it loses gravitational potential energy and gains kinetic energy. This causes the linear speed to increase. OR As the spaceship approaches the planet, the gravitational force increases between them. This results in the planet pulling the spaceship closer to the planet. The increase in the gravitational pull from the planet will cause an increase in the linear speed of the spaceship. (The gravitational force on the spaceship has a component in the direction of travel; this will increase the linear speed.)			

Q	Evidence	Achievement	Merit	Excellence
TWO (a)	$\Sigma\tau = I\alpha$ $\Sigma\tau = 58000 \times 0.020$ $\Sigma\tau = 1160$ So the torque produced by one rocket is 580 Nm.	Correct answer.		
(b)	$\omega_f^2 = \omega_i^2 + 2\alpha\theta$ $\omega_f^2 = 0.58^2 - 2 \times 0.020 \times 2\pi$ $\omega_f^2 = 0.085$ $\omega_f = 0.29 \text{ rad s}^{-1}$	correct angle conversion. i.e. $\theta = 2\pi$ OR Correct working except for angle conversion.	Correct calculation and answer.	
(c)	$\Sigma\tau = I\alpha$ As the rockets emit gas, the total mass of the spaceship will decrease. This will cause the rotational inertia to decrease. Torque is constant, so the angular acceleration will gradually increase.	States that decreased mass will cause rotational inertia (RI) to decrease. OR States that angular acceleration increases because RI decreases. *Accept inertia in place of rotational inertia.*	Decreased mass will cause rotational inertia to decrease. AND Angular acceleration increases because RI decreases. *Accept inertia in place of rotational inertia.*	

(d)(i) (ii)	The mass moves further away from the centre of rotation. This causes the rotational inertia to increase. There is no outside torque, so angular momentum is conserved. $L = I\omega$ so if the rotational inertia increases (changes), the angular speed will decrease (change), causing the period to increase (change). $L_i = L_f$ $58000 \times 0.45 = (58000 + 2740) \times \omega$ $\omega = 0.43 \text{ rad s}^{-1}$ $\omega = \frac{2\pi}{T}$ $T = \frac{2\pi}{\omega} = \frac{2\pi}{0.43} = 14.6 \text{ (or 15) s}$	RI increase, so T increase. OR Angular momentum is conserved because there is no net external torque. OR Angular momentum is conserved so angular speed decreases. OR Correct angular speed. *Accept inertia in place of rotational inertia.*	Two concepts explained and linked. OR Calculated the period correctly from an incorrect angular velocity calculated using conservation of angular momentum formula (i.e. follow-on error carried forward) *Accept inertia in place of rotational inertia.*	All concepts explained and linked AND Correct calculation and correct answer for the period. (E) ### Correct calculation and correct answer for the period. (E-) OR All concepts explained and linked. (E-) *Accept inertia in place of rotational inertia.*

Q	Evidence	Achievement	Merit	Excellence
THREE (a)	The direction of the restoring force does not change OR the direction of the restoring force remains down OR the restoring force increases as she moves away from equilibrium. OR Accept equations in the explanation ($F = -ky$) or ($F \alpha -y$) to this particular situation.	Correct answer.		

(b)	In degrees: $\sin\theta = \frac{0.08}{0.12}$ $\theta = 41.8°$ $\frac{t}{T} = \frac{\theta}{360°}$ $t = \frac{41.81° \times 8.00}{360°}$ $t = 0.928 = 0.93\ \text{s}$ In Radians: $\sin\theta = \frac{0.08}{0.12}$ $\theta = 0.73\ \text{rad}$ $t = \frac{\theta}{\omega}$ and $\omega = \frac{2\pi}{T}$ $t = \frac{\theta T}{2\pi} = \frac{0.73 \times 8.00}{2\pi}$ $t = 0.929 = 0.93\ \text{s}$ OR $y = A\sin\omega t$ and $\omega = \frac{2\pi}{T}$ Note: $\omega = 0.785\ \text{rads}^{-1}$ $0.08 = 0.12\sin\left(\frac{2\pi t}{8.00}\right)$ $\frac{2\pi t}{8.00} = \sin^{-1}\left(\frac{0.08}{0.12}\right)$ $\frac{2\pi t}{8.00} = 0.7297\ \text{rad}$ $t = \frac{0.7297 \times 8.00}{2\pi}$ $t = 0.929 = 0.93\ \text{s}$  	Correct diagram. OR Correct answer with insufficient working. OR Correct angle in either degrees or radians OR Used appropriate equation e.g. $y = A\sin\omega t$ OR Correct angular frequency $\omega = 0.785\ \text{rads}^{-1}$ ω 0.785rads^{-1}	Correct calculation and answer	

(c)	$v_{max} = \omega A$ $v_{max} = \dfrac{2\pi}{T} A$ $v_{max} = \dfrac{2 \times \pi \times 0.12}{8} = 0.0942777$ $v_{max} = 0.094 \text{ m s}^{-1}$ 	Correct answer for v_{max}. OR Graph correct shape.	Correct answer for v_{max}. AND Graph correct shape.	

(d)	$F = kx$ $k = \frac{F}{x} = \frac{4.4}{0.12} = 36.66 \text{ N m}^{-1}$ $T = 2\pi\sqrt{\frac{m}{k}}$ $8.00^2 = 4\pi^2 \frac{m}{36.66}$ $m = 59.4 \text{ kg}$ OR $E_p = \frac{1}{2}kx^2 = \frac{Fx^2}{2x} = \frac{Fx}{2} = \frac{4.40 \times 0.120}{2} = 0.264 \text{ J}$ $E_p = E_k = \frac{1}{2}mv^2$ $= \frac{1}{2}m(0.0942777)2 = 0.264$ $m = 59.4 \text{ kg}$ *OR* $a_{max} = \omega^2 A$ $a_{max} = \left(\frac{2\pi}{8}\right)^2 \times 0.12$ $a_{max} = 0.074 \text{ rad s}^{-2}$ $m = \frac{F}{a_{max}} = \frac{4.4}{0.074}$ $m = 59.4 \text{ kg}$ The period of oscillation depends on the total mass $T = 2\pi\sqrt{\frac{m}{k}}$. This formula states that if the mass is increased, the period increases also. In order to get the true mass of the astronaut, the mass of the seat and the effective mass of the spring should be omitted. However, because this information is not known and because the question states that the seat is "lightweight", the mass of the seat (and spring) can be omitted for simplicity. OR For using the energy conversion to find mass, candidate justifies WHY it is appropriate to equate kinetic energy to elastic potential energy, i.e. negligible heat losses so energy is conserved.	Correct spring constant. OR Selected the correct period equation. OR Correct energy calculation OR Calculates the maximum acceleration as 0.074 rad s^{-2}. OR States that mass of the seat and / or spring is ignored. OR States that energy is conserved if using energy conversion to find m	Allow M for follow on error for k. OR Allow M for follow on error for v using conservation of energy method. OR Allow M for the follow on error for a_{max} using Newton's second law. OR Simplifying assumption described. E.g. mass of seat (and spring) is ignored because the question stated that the seat was "lightweight". OR Candidate describes assumption that kinetic is the same size as the elastic potential energy.	Correct calculation and correct answer for the total mass AND Two supporting assumptions described (E) Correct calculation and correct answer for the total mass. (E-) OR Three or more simplifying assumptions described and linked. (E-) e.g. Simplifying assumption described. *E.g. mass of seat (and spring) is ignored because the question stated that the seat was "lightweight" and because this self-mass is ignored, we get a period lower than expected.*

Cut Scores

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