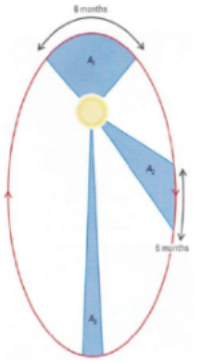
Marking Scheme

#1

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
	(a)			Areas and time periods shown correctly or described [1] $A_1 = A_2 (= A_3)$ indicated [1]  6 months	2			2		
	(b)			$\frac{mv^2}{r} = \frac{GMm}{r^2}$ [1] $v = \frac{2\pi r}{T}$ [1] Substitution and clear algebra step shown [1] **Or** $mr\omega^2 = \frac{GMm}{r^2}$ [1] $\omega = \frac{2\pi}{T}$ [1] Substitution and clear algebra step shown [1]	1	1 1		3	2	
	(c)	(i)		$\omega = \frac{2\pi}{(7.7 \times 3\,600)}$ or $2.26(7) \times 10^{-4}$ rads^{-1} seen [1] $M = \frac{(2.27 \times 10^{-4})^2 \times (9.4 \times 10^6)^3}{6.67 \times 10^{-11}}$ substitution and re-arrangement [1] $M = 6.39[8] \times 10^{23}$ k[g] [1]		3		3	3	
		(ii)	I	Substitution into $V_g = -\frac{GM}{R}$ i.e. $V_g = -\frac{6.67 \times 10^{-11} \times 6.4 \times 10^{23}}{9.4 \times 10^6}$ [1] $V_g = -4.5(4) \times 10^6$ [J kg^{-1}] [1]	1	1		2	2	
			II	V_g at orbit of Deimos = $-\frac{6.67 \times 10^{-11} \times 6.4 \times 10^{23}}{2.35 \times 10^7}$ $= -1.8(2) \times 10^6$ J kg^{-1}[1] $\Delta V = -1.82 + 4.54 = 2.72$ M[J kg^{-1}] [1] Energy available per kg of fuel = $0.6 \times 4.4 = 2.64$ M[J kg^{-1}] [1] Scientists should not attempt manoeuvre [1] **[ecf** based on calculations]			4	4	3	
		(iii)		One of: • g is not constant [over the distance between orbits] • g decreases as height increases • work done per metre decreases as height increases • field is not uniform		1		1		
				Question total	**4**	**7**	**4**	**15**	**10**	**0**

#2

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
7	(a)	(i)	Substitution: $T = 2\pi\sqrt{\frac{(5.2\times10^{9})^{3}}{6.67\times10^{-11}\times6.2\times10^{28}}}$ [or mass on bottom line = $(6.0 \times 10^{28} + 2.0 \times 10^{27})$] [1] $T = 1.16 \times 10^{6}$ [s] [1] If mass of planet ignored → $T = 1.18 \times 10^{6}$ [s] award 1 mark	1	1		2	1	
		(ii)	Substitution: $r = \frac{2\times10^{27}\times5.2\times10^{9}}{6.2\times10^{28}}$ [1] $r = 1.68 \times 10^{8}$ [m] accept 1.7×10^{8} [m] [1]	1	1		2	1	
	(b)		Use of (a)(i) and (ii) ecf - $v_{star} = \frac{2\pi\times1.68\times10^{8}}{1.16\times10^{6}}$ [1] $v_{star} = 910$ [ms^{-1}] [1] Use of Doppler shift: **Either:** $\Delta\lambda = \frac{910\times656.3\times10^{-9}}{3\times10^{8}}$ [m] or $\Delta\lambda = \frac{910\times656.3}{3\times10^{8}}$ n[m] [1] $\Delta\lambda \approx 1.99$ p[m] seen ∴ consistent [1] **Or:** $v_{star} = \frac{2\times10^{-12}\times3\times10^{8}}{656.3\times10^{-9}}$ [1] $v_{star} = 914$ [ms^{-1}] ∴ consistent [1]			4	4	3	
	(c)		Planet moves in front of star			1	1		
			Question 7 total	**2**	**2**	**5**	**9**	**5**	**0**

#3

Question			Marking details	Marks available AO1	AO2	AO3	Total	Maths	Prac
	(a)		Line drawn from Sun to planet..... (1) .....will sweep out equal areas reference to $A_1 = A_2 = A_3$ (1) .....in equal time intervals / 6 months (1)	3			3		
	(b)		$\frac{mv^2}{r} = \frac{GMm}{r^2}$ (1) $v = \frac{2\pi r}{T}$ (1) Substitution and clear algebra step shown (1) **Or:** $mr\omega^2 = \frac{GMm}{r^2}$ (1) $\omega = \frac{2\pi}{T}$ (1) Substitution and clear algebra step shown (1)	1 1	1		3	3	
	(c)	(i)	1.45 years = 4.573×10^7 [s] (1) Substitution into $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$ i.e. $\frac{0.052}{486.14} = \frac{v}{3.0 \times 10^8}$ (1) $v = 3.209 \times 10^4$ [m s^{-1}] (1) $r = \frac{vT}{2\pi} = \frac{3.209 \times 10^4 \times 4.573 \times 10^7}{2\pi}$ $= 2.34 \times 10^{11}$ [m] (1) **Alternative** for 4.573×10^7 see $1.45 \times 86\,400 \times 365$	1	1 1 1		4	4	
		(ii)	Assumption CoM at/near centre of neutron star or M_1 much greater than M_2 (1) **Either**: $M = \frac{v^2 r}{G}$ (1) $M = \frac{(3.209 \times 10^{\ })^2 \times 2.34 \times 10^{11}}{6.67 \times 10^{-11}}$ (substitution) (1) **ecf** on v $M = 3.6 \times 10^{30}$ [kg] **and** valid conclusion (1)						
		(ii)	**Alternative:** $M = \frac{4\pi^2 r^3}{GT^2}$ (1) $M = \frac{4\pi^2 \times (2.34 \times 10^{\ })^3}{6.67 \times 10^{-11} \times (4.573 \times 10^{\ })^2}$ (substitution) (1) **ecf** on T $M = 3.6 \times 10^{30}$ [kg] **and** valid conclusion (1)			4	4	4	
			Question total	**6**	**4**	**4**	**14**	**11**	**0**

#4

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
	(a)			Essentially $F = ma$ (1) $u\frac{\Delta m}{\Delta t}$ is rate of change of momentum for gases (1) Hence it is (equal & opposite to force on rocket (of mass m) (1)	3			3	1	3
	(b)			Mass will be (approximately) constant (1) u and $\frac{\Delta m}{\Delta t}$ constant from paragraph 3 (1) Mass m is large and $\frac{\Delta m}{\Delta t}$ is small (1)		3		3	1	3
	(c)	(i)		Unit is s^2 not s OR accept wrong unit for t^2	1			1		1
		(ii)		Subtracting 0.02 s (1) Due to electromagnet delay OR systematic error in t (1)		2		2		2
	(d)			$x=ut+0.5at^2$ quoted or its use implied (1) Leading to $t^2 = \frac{2xm}{F}$ OR equivalent (1) But $\frac{t^2}{m}$ = gradient and x = 1.4 so gradient = $\frac{2 \times 1.4}{F}$ (1)		3		3	2	3
	(e)			Multiplication implied and reference to equation or reference to rate of change of momentum		1		1		1
	(f)			Gradient equated to $\frac{2.8}{F}$ (1) Gives 4.41 [N] or 4.409 [N] and so correct (1) **Alternative:** **or** Gradient = $\frac{2.8}{4.4}$ (1) = 0.64 or 0.636 so consistent (1)			2	2	2	2
	(g)	(i)		Change in wavelength/frequency (1) Due to motion (of source relative to observer) (1)	2			2		
		(ii)		Point telescope/device at [Accept: observe] exhaust/gases (1) Spectral analysis/prism/diffraction grating [Accept: pick out one wavelength or equivalent] (1) Use Doppler equation or $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$ (1)			3	3		
				Question total	**6**	**9**	**5**	**20**	**6**	**15**

#5

Question				Marking details	Marks available					
					AO1	AO2	AO3	Total	Maths	Prac
	(a)			Substitution i.e. $\rho = \frac{3(2.20 \times 10^{-18})^2}{8\pi(6.67 \times 10^{-11})}$ [1] $\rho = 8.66 \times 10^{-27}$ kg m^{-3} **(unit mark)** [1]	1	1		2	2	
	(b)			Increase in distance = $(2 \times 10^9 \times 365 \times 24 \times 3\,600 \times 2.2 \times 10^{-18})R$ (= 0.14R) [1] R increased by 14 % [1] Nearly 15 %, justified [1] **Alternative:** $D \propto \frac{1}{H_0}$ or $D = \frac{k}{H_0}$ [1] Appropriate algebra e.g. $D_1 = \frac{k}{1.44 \times 10^{10}}$ [years] and $D_2 = \frac{k}{2 \times 10^9 \times 1.44 \times 10^{10}}$ and/or $k = \frac{D_2}{D_1} = \frac{1.64}{1.44}$ [= 1.14] [1] Hence k approx. = 14 % shown (approx. 15 %) [1]			3	3	2	
	(c)	(i)		$\frac{\Delta\lambda}{410}$ calculated or shown: i.e. $\frac{65}{410}$ or 0.16 seen [1] v calculated = $0.16 \times 3 \times 10^8 = 4.8 \times 10^7$ [m s^{-1}] [1]		2		2	2	
		(ii)		Substitution and re-arrangement: Distance = $\frac{4.8 \times 10^7}{2.2 \times 10^{-18}}$ (**ecf** on v) [1] Distance = 2.18×10^{25} [m] [1]		2		2	2	
		(iii)		Use of $E_k = \frac{3}{2}kT$ $E_k = 1.47 \times 10^{-19}$ [J] [1] = 0.9[2 eV] [1]		2		2	1	
				Question total	**1**	**7**	**3**	**11**	**9**	**0**

#6

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
4	(a)	(i)	Some context e.g. Consider matter within [shell of] radius R (assuming homogenous universe) [credit from diagram] Mass within shell = $\frac{4}{3}\pi R^3 \times \rho$ (1) $\frac{1}{2}mv^2 - \frac{GMm}{R} = 0$ (or equivalent) (1) Substitution of $v = H_0R$ (or equivalent, e.g. H_0D) (1) Convincing algebra (1)	4			4	3	
		(ii)	Correct substitution of H_0 and G leading to $\rho_c = 8.7 \times 10^{-27}$ kg m^{-3} (1) $\frac{8.7 \times 10^{-27}}{1.66 \times 10^{-27}} = 5.2$ (m^{-3}) (approx. 5 atoms of hydrogen m^{-3}) (1) Alternative for 2nd mark Calculation of mass of 5H m^{-3} using 5×molar mass / $N_A \rightarrow 5.3 \times 10^{-27}$ kg m^{-3} (1) **Alternative** Density of 5 H atoms m^{-3} $= 5 \times 1.66 \times 10^{-27}$ $= 8.3 \times 10^{-27}$ kg m^{-3} (1) Correct substitution of H_0 and G leading to $\rho_c = 8.7 \times 10^{-27}$ kg m^{-3} + comment [e.g. similar] (1)		2		2	1	
	(b)	(i)	Due to expansion of universe [or space-time] / cosmological red shift or galaxy is moving away from earth or Doppler shifted (1) 'Red shift' only is not enough	1			1		
		(ii)	Use of $\frac{\Delta\lambda}{\lambda} = \frac{v}{c}$ where $\frac{\Delta\lambda}{\lambda} = 0.16$ (1) $0.16 \times 3.00 \times 10^8 = 4.8 \times 10^7$ m s^{-1} (1) $D = \frac{4.8 \times 10^7}{2.20 \times 10^{-18}} = 2.18 \times 10^{25}$ m (1)	1	1 1		3	2	
	(c)		Assuming constant recession speeds / universe expands at a constant rate / H_0 constant (since Big Bang) (1) Age of Universe $\approx \frac{1}{H_0} \approx 4.5[5] \times 10^{17}$ s (1) $= 1.4[4] \times 10^{10}$ [years] (1)	1	1 1		3	2	
			Question 4 total	**7**	**6**	**0**	**13**	**8**	**0**

#7

Question			Marking details	Marks available				Maths	Prac
				AO1	AO2	AO3	Total		
5			Indicative content: 1. Reference to $\frac{mv^2}{R} = \frac{GMm}{R^2}$ or equivalent e.g. $v = \left(\frac{GM}{R}\right)^{1/2}$ 2. For small R theory agrees with observation 3. $v^2 \propto$ observed M 4. Observations of [baryonic /ordinary matter show a concentration of mass at the centre leading to …. 5. … For large R theory predicts: $v \propto R^{-1/2}$ [shown by dotted line] [based on observed baryonic matter] 6. Observed line shows v constant or greater than expected. 7. Indicates $M \propto R$ or M greater than expected [or accept even distribution of matter] 8. M is not observed however, indicating missing mass/ dark matter. [possible link to Higgs boson] 9. All stars [matter] orbit centre of galaxy 10. Curves extend beyond visible disc 11. Orbital speeds [of stars and gas clouds] measured using Doppler effect.	6			6		
			5-6 marks **At least 5/6 clear points made** *There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.* **3-4 marks** **At least 3/4 clear points made.** *There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure.* **1-2 marks** **At least 2 clear points made.** *There is a basic line of reasoning which is not coherent, largely irrelevant, supported by limited evidence and with very little structure.* **0 marks** *No attempt made or no response worthy of credit.*						
			Question 5 total	**6**	**0**	**0**	**6**	**0**	**0**