Marking Scheme

#1

Question			Marking details	Marks available AO1	AO2	AO3	Total	Maths	Prac
3	*(a)*		Constant velocity (1) Substitution of $D = vT$ into Hubble's law and convincing algebra (1)	2			2	1	
	(b)		Substitution of H_0 & 3.09×10^{22} m into Hubble's law (gives 68 000 m/s) (1) Substitution [of at least c and λ] into Doppler equation (1) $\Delta\lambda = \frac{68\,000 \times 486.1[\times 10^{-9}]}{3 \times 10^{8}}$ seen (1) or 0.11 nm	1 1	1		3	3	
	(c)		Correct method for obtaining velocities e.g. $\frac{c\Delta\lambda}{\lambda}$ (1) Blue shift speed is [-]2v (-136 000) (1) and redshift speed is 6v (407 000 / 408 000) (1) Recessional speed = 2v (136 000) (1) Rotational speed = 4v (272 000) (1) NB Final mark awarded only if recessional speed and rotational speed clearly indentified.		5		5	5	
	(d)		**Collation points** C1 Doppler/red/blue shift measured C2 of [known] lines / wavelengths C3 velocity calculated / measured / linked to $\Delta\lambda / \frac{\Delta\lambda}{\lambda} = \frac{v}{c}$ C4 for various distances from centre of galaxy [can be credited from good graph] C5 absorption spectrum used C6 mention of [large] telescope / analysis of light / em radiation observed C7 mention of spectrometer / prism / grating / spectral analysis **Theory points** T1 Doppler shift explained e.g. redshift, moving away T2 Doppler equation quoted or shift dependency on velocity mentioned T3 Orbital speed increases with mass / $v = \sqrt{\frac{GM}{r}}$ T4 Orbital speed decreases with radius (theoretically) OR graph or equation T5 Theoretical speed based on visible/baryonic mass OR graph **Results & Conclusion points** R1 Speed does not decrease with radius / actual speed too large OR graph R2 Hence extra mass R3 Dark matter linked to extra mass R4 Possible link to Higgs boson / WIMPS / CMBR	6			6		
			5 - 6 marks Expect 8-16 points There is a sustained line of reasoning which is coherent, relevant, substantiated and logically structured. **3 - 4 marks** Expect 5-7 points There is a line of reasoning which is partially coherent, largely relevant, supported by some evidence and with some structure. **1 - 2 marks** Expect 1-4 points 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 3 total	**10**	**6**	**0**	**16**	**9**	**0**

#2

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(a)	(i)	Use of the equation $\frac{M_2 d}{(M_1 + M_2)} = x$ even if wrong M_2 (1) $\frac{9.2 \times 10^{24} \times 5.3 \times 10^{10}}{(9.5 \times 10^{29} + \{9.2 \times 10^{24}\})}$ seen (1) ({ +9.2 × 10^{24} } can be omitted from the above equation) **or** 513 263 [m] seen etc.	1 1			2	2	
		(ii)	$v = \frac{2\pi r}{T}$ applied or $v = \omega r$ and $\omega = \frac{2\pi}{T}$ combined (1) Conversion of 130 days (130 × 24 × 3 600) (1) Answer = 0.287 [m s^{-1}] (**ecf** on day conversion) (1)	1	1 1		3	3	
		(iii)	Redshift is small **or** the redshift is proportional to velocity **or** small $\Delta\lambda$ **or** shown using the Doppler equation (1) Small wavelength change is difficult to measure **or** shifted wavelength is too close to the original (1)		2		2		
	(b)	(i)	$F = \frac{GMm}{r^2}$ used (1) Answer = 2.08 × 10^{23} [N] (1)	1	1		2	2	
		(ii)	Method for obtaining stress i.e. $\frac{F}{A}$ (1) 1.35 × 10^9 [Pa] (1) Correct conclusion e.g. the steel bar would break **ecf** (1) Theory doesn't work / Newton's grav law used successfully for centuries / won't work for elliptical orbits / would melt (1) **Alternative:** Use of $F = \sigma A$ (1) F = 6.9 × 10^{22} [N] (1)			4	4	2	
	(c)	(i)	PE = $-\frac{GMm}{r}$ used N.B. **ecf** if PE = Fr used (1) Answer = [-]1.10 × 10^{34} [J] (1)	1	1		2	2	
		(ii)	Realising KE is involved (1) Correct variation with distance for KE or velocity **or** as PE increases KE decreases or converse (1)			2	2		
			Question total	**5**	**6**	**6**	**17**	**11**	**0**

#3

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
	(a)		Microwave laser or amplifier or equivalent (1) from water [molecules] or water clouds or steam (1) in gas disk around (supermassive) black hole (or quasar) (1) pumping or excitation provided by collisions (accept light) (1) (em radiation) propagates outwards (away from black hole) **or** reference to population inversion (1) Treat as neutral reference to watermaser. (Don't award the individual marks if later contradicted)	1 1 1	 1 1		5		
	(b)		Appropriate wavelength or energy or frequency chosen e.g. 400 nm-700 nm or 2-3 eV or 4-8 × 10^{14} Hz (1) Valid method for obtaining ratio of frequencies, wavelength or energy (1) Answer 35 m[s] – 80 m[s] (1)	1	 1 1		3	2	
	(c)		$\frac{3\,300}{68.9}$ (1) 48 [Mpc] (1)		 2		2	2	
	(d)		Measure the velocity using Doppler shift or use of Doppler equation (1) at different times (1) acceleration = rate of change of velocity (1) **Alternative:** Measure the velocity using Doppler shift (1) Obtain v_{max} (1) $a = \frac{v^2_{max}}{r}$ or equivalent e.g. use v and r to calculate a (1)			3	3		
	(e)	(i)	Use of $r = \frac{v^2}{a}$ (1) Acceleration conversion i.e. /365/24/3600 (1) Answer = 8.8 × 10^{14} [m] or 8.8 × 10^{11} k[m] (1)			3	3	3	
		(ii)	Approximation used i.e. $D = \frac{r}{\theta}$ (1) Answer = 7.8 × 10^{14} [m] (1) Hence consistent (since overlap) i.e. valid conclusion **based on calculations** (1) Comparing e.g. 1.53 ± 0.15 and 1.73 ± 0.17 but also accept combined error = 20% or 8.8 × 10^{14} is less than 20% bigger than 7.8 × 10^{14} (1)			4	4	2	
			Question total	**4**	**6**	**10**	**20**	**9**	**0**

Question			Marking details	Marks available					
				AO1	AO2	AO3	Total	Maths	Prac
3	(a)	(i)	Planets / masses orbit in ellipses (with the Sun at a focus) (1) [Line from planet to Sun] sweeps equal area(s) in equal time(s) or sweeps area at a constant rate (1) Sun at a focus & line from planet to Sun (or radius vector) (1)	3			3		
		(ii)	$\frac{GMm}{r^2}=\frac{mv^2}{r}$ or $mr\omega^2$ (1) Substitution of $\omega=\frac{2\pi}{T}$ or equivalent i.e. $v=\frac{2\pi r}{T}$ (1) Intermediate step seen e.g. $\frac{GMm}{r^2}=m\frac{4\pi^2}{T^2}r$ (1) **Alternative:** $T=2\pi\sqrt{\frac{d^3}{G(M_1+M_2)}}$ (1) $M_2 = 0$ or implied (1) $d = r$ and $M_1 = M_E$ (1)	3			3	3	
	(b)		Period of geostationary = 1 day (24 hr etc.) (1) Use of Kepler e.g. $\frac{T_1^2}{r_1^3}=\frac{T_2^2}{r_2^3}$ [accept substitution with 5.97×10^{24}] (1) Correct answer = 27.2 [days] (2.35×10^6 s) (1) **Alternative:** Substitution into period equation (1) Algebra (1) Correct answer = 27.2 [days] (2.32×10^6 s) (1)	1 1	1		3	2	
	(c)		Assumption - Radius cannot be less than r_E (or inside Earth's surface etc.) or ignore mountains/air resistance accept no atmosphere or Earth is totally smooth (1) Use of Kepler or accept equation use again (1) Correct answer = 1.42 h, $\frac{1}{16.9}$ of a day, 5 100 s etc. (accept slightly larger due to, e.g. r_E = 6 470 km to be above atmosphere etc. which gives 1.45 h) (1)		3		3	2	
			Question 3 total	**8**	**4**	**0**	**12**	**7**	**0**