*[**Marking Scheme**]* *Theoretical Question 1*

When will the Moon become a Synchronous Satellite?

(1) 3.0	0.4	*location* of center of mass *C* ➢ 0.2 for distance to Earth ➢ 0.2 for distance to Moon
	0.4	*Orbital* angular momentum of the *Moon* ℓ_M ➢ 0.2 for formula ➢ 0.2 for numerical value
	0.4	*spin* angular momentum of the *Moon* S_M ➢ 0.2 for formula ➢ 0.2 for numerical value
	0.4	*Orbital* angular momentum of the *Earth* ℓ_E ➢ 0.2 for formula ➢ 0.2 for numerical value
	0.4	*spin* angular momentum of the *Earth* S_E ➢ 0.2 for formula ➢ 0.2 for numerical value
	0.2	knowing total angular momentum of a system is the *sum* of orbital and spin angular momenta
	0.8	*total* angular momentum of the Earth-Moon system *L* ➢ 0.2 for order of magnitude ➢ 0.4for value to two significant digits ➢ 0.2for unit
(2) 3.0	0.8	Newton's form of *Kepler's third law* $\omega^2 r^3 = G(M_E + M)$ ➢ 0.6 for $\omega^2 r^3$ = constant ➢ 0.2 for expression of constant $G(M_E + M)$
	0.4	realizing total orbital angular momentum $\ell = \ell_E + \ell_M$ is a function of ω or alone
	0.2	realizing spin angular momentum of the Moon is negligible
	0.4	resorting to the law of conservation of total angular momentum
	1.2	*period of rotation* of the Earth *T* ➢ 0.3 for order of magnitude in units of second ➢ 0.4 for value to two significant digits ➢ 0.5 for providing an equation for finding *T*
(3) 4.0	0.2	0.2 for knowing $\Gamma = (\frac{r_0}{r})^6 \Gamma_0$
	0.4	realizing *relation between torque and rate of slowdown* of Earth's rotation: $dS_E / dt = \Gamma$
	0.4	concluding -Γ is equal to rate of increase of *total orbital angular momentum* of the Earth-Moon system: $d\ell / dt = -\Gamma$
	1.0	*current value* of the *torque* Γ_0 ➢ 0.2 for realizing ℓ is related to *r* ➢ 0.3 for converting the derivative $d\ell / dt$ to dr / dt

		➢ 0.4 for value of Γ_0 ➢ 0.1 for unit of torque
	0.6	*converting the derivative* $d\ell / dt$ to $d\omega / dt$ ➢ 0.1 for realizing ℓ is related to ω ➢ 0.1 for realizing Γ is related to ω ➢ 0.4 for converting $d\ell / dt = -\Gamma$ into a differential equation for ω
	0.6	*providing* an *equation* for the solution of t_f
	0.8	*estimate of time* t_f ➢ 0.3 for order of magnitude in units of second ➢ 0.4 for value to two significant digits ➢ 0.1 for value in years