[Marking Scheme] *Theoretical Question 2*

Motion of an Electric Dipole in a Magnetic Field

(1) 2.8	1.0	(1a) ➢ 0.2 obtain correct result for the *total force* ➢ 0.2 write down the correct *equation of motion* for the *center of mass* *eq.(1) ➢ 0.2 obtain correct result for the *total torque* with respect to the center of mass ➢ 0.2 write down the correct *equation of motion* for *rotation* around the center of mass *eq.(2) ➢ 0.2 obtain correct result for the *moment of inertia* for rotation around the center of mass of the dipole *eq.(3)
	1.0	(1b) ➢ 0.5 obtain correct expression for the *conserved quantity* $\vec{P}$ *eq.(4) ➢ 0.2 knowing that *total kinetic energy* is *conserved* ➢ 0.3 obtain the correct expression for E in terms of v_{CM} and ω *eq.(5)
	0.8	(1c) prove that J is conserved ➢ 0.3 for realizing the time derivative of J is zero ➢ 0.5 for an explicit proof

(2) 7.2	1.2	(2a) ➢ 0.2 knowing to *use the proper conservation laws* ➢ 0.2 knowing to *use the initial condition* to obtain the value of the conserved quantities ➢ 0.2 write down eq.(12) correctly ➢ 0.4 knowing $\dot{\varphi}$ *should not vanish* ➢ 0.2 obtain the correct *expression for* ω_c *eq.(14)
	3.0	(2b) ➢ 0.3 knowing to *use the conserved quantity J* ➢ 0.3 knowing to *use the initial condition* to obtain the value of *J* ➢ 0.2 knowing that $x_{CM} \geq 0$ ➢ 0.2 knowing that maximum distance d_m is reached *when* ω *takes its minimum value* ➢ 0.2 knowing to *discuss the cases* $\omega_0 < \omega_c$, $\omega_0 > \omega_c$ and $\omega_0 = \omega_c$ *eq.(17) ➢ 0.6 obtain the correct *expression of* d_m for $\omega_0 < \omega_c$ ➢ 0.6 obtain the correct *expression of* d_m for $\omega_0 > \omega_c$ *eq.(18) ➢ 0.2 knowing that it takes infinite *time to reach the turning point* for $\omega_0 = \omega_c$ ➢ 0.4 obtain the correct *expression of* d_m for $\omega_0 = \omega_c$
	3.0	(3c) ➢ 0.5 write down the *Coulomb force* term correctly *eq.(20) ➢ 0.2 knowing that *there is a centrifugal force* ➢ 0.8 write down the *centrifugal force term* correctly *eq.(21) ➢ 0.5 knowing that *there is a magnetic force* term due to center of mass motion ➢ 1.0 write down the *magnetic force term* correctly *eq(22)