

[Marking Scheme]**Theoretical Question 2*****Motion of an Electric Dipole in a Magnetic Field***

(1) <div>2.8</div>	1.0	(1a) <ul style="list-style-type: none"> ➤ 0.2 obtain correct result for the <i>total force</i> ➤ 0.2 write down the correct <i>equation of motion</i> for the <i>center of mass</i> *eq.(1) ➤ 0.2 obtain correct result for the <i>total torque</i> with respect to the center of mass ➤ 0.2 write down the correct <i>equation of motion</i> for <i>rotation</i> around the center of mass *eq.(2) ➤ 0.2 obtain correct result for the <i>moment of inertia</i> for rotation around the center of mass of the dipole *eq.(3)
	1.0	(1b) <ul style="list-style-type: none"> ➤ 0.5 obtain correct expression for the <i>conserved quantity</i> \vec{P} *eq.(4) ➤ 0.2 knowing that <i>total kinetic energy</i> is <i>conserved</i> ➤ 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 <ul style="list-style-type: none"> ➤ 0.3 for realizing the time derivative of J is zero ➤ 0.5 for an explicit proof

(2) <div>7.2</div>	1.2	(2a) <ul style="list-style-type: none"> ➤ 0.2 knowing to <i>use the proper conservation laws</i> ➤ 0.2 knowing to <i>use the initial condition</i> to obtain the value of the conserved quantities ➤ 0.2 write down eq.(12) correctly ➤ 0.4 knowing $\dot{\phi}$ <i>should not vanish</i> ➤ 0.2 obtain the correct <i>expression for</i> ω_c *eq.(14)
	3.0	(2b) <ul style="list-style-type: none"> ➤ 0.3 knowing to <i>use the conserved quantity J</i> ➤ 0.3 knowing to <i>use the initial condition</i> to obtain the value of J ➤ 0.2 knowing that $x_{CM} \geq 0$ ➤ 0.2 knowing that maximum distance d_m is reached <i>when</i> ω <i>takes its minimum value</i> ➤ 0.2 knowing to <i>discuss the cases</i> $\omega_0 < \omega_c$, $\omega_0 > \omega_c$ and $\omega_0 = \omega_c$ *eq.(17) ➤ 0.6 obtain the correct <i>expression of</i> d_m for $\omega_0 < \omega_c$ ➤ 0.6 obtain the correct <i>expression of</i> d_m for $\omega_0 > \omega_c$ *eq.(18) ➤ 0.2 knowing that it takes infinite <i>time to reach the turning point</i> for $\omega_0 = \omega_c$ ➤ 0.4 obtain the correct <i>expression of</i> d_m for $\omega_0 = \omega_c$
	3.0	(3c) <ul style="list-style-type: none"> ➤ 0.5 write down the <i>Coulomb force</i> term correctly *eq.(20) ➤ 0.2 knowing that <i>there is a centrifugal force</i> ➤ 0.8 write down the <i>centrifugal force term</i> correctly *eq.(21) ➤ 0.5 knowing that <i>there is a magnetic force</i> term due to center of mass motion ➤ 1.0 write down the <i>magnetic force term</i> correctly *eq.(22)