Theory Marking Sheet

Q3: Space Debris

APhO 2017, Yakutsk, Russia

Marker_____ Student_____

TOTAL_____

Subq.	№	Statement	Pts.	Marker		Consensus	
				Stat.	Subq.	Stat.	Subq.
A1 (0.2)	1	$\omega_x = \frac{L\cos\theta}{J_x}$	0.1				
	2	$\omega_y = \frac{L\sin\theta}{J_y}$	0.1				
A2 (0.4)	3	$E_x = \frac{J_x\omega_x^2}{2}$	0.1				
	4	$E_y = \frac{J_y\omega_y^2}{2}$	0.1				
	5	$E(\theta) = \frac{L^2}{2J_y} + \frac{L^2}{2}\left(\frac{1}{J_x} - \frac{1}{J_y}\right)\cos^2\theta$	0.2				
	6	*if no (5)* Correct energy not in terms of L, J, $\cos\theta$	0.1*				
A3 (1.2)	7	$\psi = 2\theta_0$	1.2				
	8	*if no (7)* $\theta = \text{const}$	1.0*				
	9	*if no (7,8)* $L = \text{const}$	0.2*				
	10	*if no (7,8)* $E = \text{const}$	0.2*				
	11	*if no (7,8)* Correct formula for θ in terms of given parameters	0.2*				
A4 (2.0)	12	$\Omega(\mathrm{t}) = \frac{L}{J_y}$	1.0				
	13	$\gamma_s(t) = 0$	0.5				
	14	$\omega_s(t) = \left(\frac{1}{J_x} - \frac{1}{J_y}\right)L\cos\theta_0$	0.5				
	15	*if no (12,14)* $\omega_s + \Omega\cos\theta = \frac{L\cos\theta}{J_x}$	0.25*				
	16	*if no (12,14)* $\Omega\sin\theta = \frac{L\sin\theta}{J_y}$	0.25*				
B1 (0.6)	17	$\theta_2 = \frac{\pi}{2}$	0.6				
	18	*if no (17)* $\cos\theta_2 = 0$	0.3*				

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B2 (0.6)	19	$\omega_2 \approx \frac{5}{9}\text{rad/s} \approx 0.556\ \text{rad/s}$	0.6				
	20	*if no (19)* $\omega_2 = \frac{\omega_1}{J_y}\sqrt{J_x^2 \cos^2\gamma_1 + J_y^2 \sin^2\gamma_1}$	0.4*				
	21	*if no (19,20)* rotation at $t = \infty$ about *y* axis	0.2*				
C1 (1.0)	22	$\mu_x = 0$	0.1				
	23	$\mu_y = -\frac{2\pi}{3\rho} DR^4 \dot{B}$	0.8				
	24	$\mu_z = 0$	0.1				
	25	*if no (23)* $d\mu = \frac{\pi}{2\rho} DR^4 \dot{B} \sin^3\varphi\, d\varphi$	0.7*				
	26	*if no (23,25)* Expression for elementary Ampere's torque which explicitly corresponds to (34)	0.7*				
	27	*if no (23,25,26)* Expression for elementary Ampere's force which explicitly corresponds to (34)	0.6*				
	28	*if no (23,25-27)* $dI = \frac{1}{2\rho} DR^2 \dot{B} \sin\varphi\, d\varphi$	0.5*				
	29	*if no (23,25-28)* $r(d\varphi) = \frac{2\pi\rho R \sin\varphi}{DRd\varphi}$	0.2*				
	30	*if no (23,25-28)* Faraday's law ($\mathcal{E} = -\dot{\Phi}$)	0.2*				
	31	if no (22-30) and 34 is correct	0.7*				
C2 (0.3)	32	$M_x = 0$	0.1				
	33	$M_y = 0$	0.1				
	34	$M_z = \frac{2\pi}{3\rho} DR^4 B\dot{B} \sin\alpha$	0.1				

Subq.	№	Statement	Pts.	Marker		Consensus	
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C3 (0.4)	35	$B_{EX}(u) = -\frac{3}{2}B_0 \sin 2u$	0.15				
	36	$B_{EY}(u) = \frac{1}{2}(3\cos 2u - 1)B_0$	0.15				
	37	$B_{EZ}(u) = 0$	0.1				
	38	*if no (35) or (36)* $B_0 = \frac{\mu_0 \mu_E}{4\pi}\frac{1}{R_O^3}$	0.1*				
	39	*if no (35, 38)* $B_{EX}(u) = -\frac{3\mu_0 \mu_E}{8\pi}\frac{1}{R_O^3}\sin 2u$	0.05*				
	40	*if no (36, 38)* $B_{EY}(u) = -\frac{\mu_0 \mu_E}{8\pi}\frac{1}{R_O^3}(3\cos 2u - 1)$	0.05*				
C4 (1.3)	41	$M_X = 0$	0.1				
	42	$M_Y = 0$	0.1				
	43	$M_Z = \frac{2\pi}{3\rho}DB_0^2R^4\left(\frac{3\pi}{T}(3-\cos 2u) - \frac{\omega}{2}(5-3\cos 2u)\right)$	1.1				
	44	*if no (43)* vector form for $\dot{\vec{B}}$ explicitly equivalent to (45-47)	0.6*				
	45	*if no (43,44)* $\dot{B}_x = (48) + (51)$	0.2*				
	46	*if no (43,44)* $\dot{B}_y = (49) + (52)$	0.2*				
	47	*if no (43,44)* $\dot{B}_z = 0$	0.2*				
	48	*if no (43,44,45)* orbital part of $\dot{B}_x$: $(B_X'(u)\cos\beta + B_Y'(u)\sin\beta)\frac{2\pi}{T}$	0.1*				
	49	*if no (43,44,46)* orbital part of $\dot{B}_y$: $(-B_X'(u)\sin\beta + B_Y'(u)\cos\beta)\frac{2\pi}{T}$	0.1*				
	50	*if no (43,44,47)* orbital part of $\dot{B}_z = 0$	0.1*				
	51	*if no (43,44,45)* rotational part of $\dot{B}_x$: $(-B_X(u)\sin\beta + B_Y(u)\cos\beta)\omega$	0.1*				
	52	*if no (43,44,46)* rotational part of $\dot{B}_y$: $(-B_X(u)\cos\beta - B_Y(u)\sin\beta)\omega$	0.1*				
	53	*if no (43,44,47)* rotational part of $\dot{B}_z = 0$	0.1*				
	54	*if no (43)* $\dot{\vec{B}} = \dot{\vec{B}}_{orbital} + \dot{\vec{B}}_{rotational}$	0.1*				
	55						

C5 (1.0)	56	$\omega(t) = \frac{18\pi}{5T} + \left(\omega_2 - \frac{18\pi}{5T}\right) e^{-\delta t}$, $\delta = \frac{5\pi}{3J_y\rho} DB_0^2 R^4$	1.0				
	57	*if no (56)* $\langle M_Z \rangle = \frac{2\pi}{3\rho} DB_0^2 R^4 \left(\frac{9\pi}{T} - \frac{5\omega}{2}\right)$	0.5*				
	58	*if no (56, 57)* $\langle M_Z \rangle \sim (A - B\omega), A \neq 0, B > 0$	0.25*				
	59	*if no (56-58)* explicit attempt to average M_Z is present	0.15*				
	60	*if no (56)* $L_Z = J_y\omega$	0.25*				
	61	*if no (56)* $\omega(t) = \omega_2 e^{-\delta t}$, $\delta = \frac{5\pi}{3J_y\rho} DB_0^2 R^4$	0.15*				
	62	*if no (56,61)* $\omega(t) = \omega_2 e^{-\kappa t}$, $\kappa > 0$	0.1*				
C6 (1.0)	63	1.8	1.0				

Notes:

* mark the lines that are applied only if the points for the answer sheet questions are not given

Error propagation rules:

Rule 1. Errors are traced back to the origin and are penalized only in those statements, where they occur
Rule 2. Rule 1 does not apply whenever there is a clear **physical** explanation, why the obtained erroneous results cannot be true (e.g., angular velocity tends to infinity in C5, or $\mu \sim \rho$ in C1)
Rule 3. If rule 1 does not apply, all points are halved for the statements influenced by the error and following the question, where the physical explanation can be observed.
Special rule for C6. Points are given only for the exact result (no remorse).