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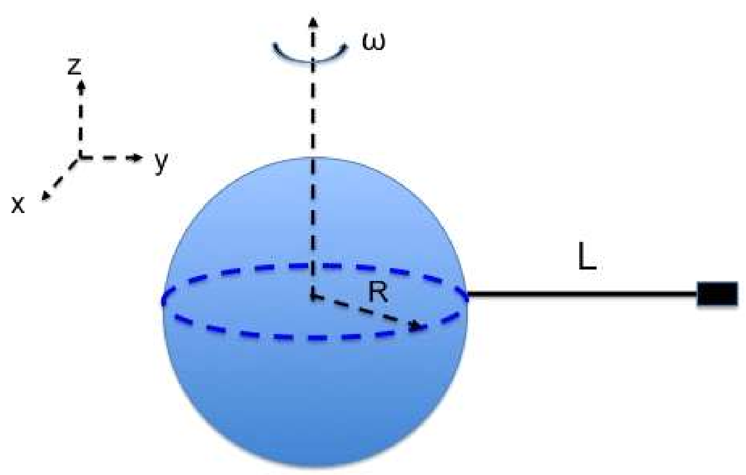
과목명 : 고전역학 **2017.04.28. 시행**

1. [20 points] Assume that the earth has radius R and mass M and rotates at angular velocity ω. The earth is a homogeneous sphere as shown in below figure.

(a) [5 points] When the origin is placed at the center of the sphere, calculate the moments of inertia for x, y and z-axis.

Some scientists and engineers have proposed a “space elevator”. According to their proposal, long and stretchy cable made by carbon nanotube, it can tolerate in stationary orbit around the equator as shown in below figure. Using this cable, we can send an elevator to space station and the cost will be cheaper than a space shuttle. In the figure, the cable has length L and mass m, and reaches to the earth’s surface.



(b) [10 points] What is the tension of the cable? Assume the density of the cable is uniform.

(c) [5 points] How long should the cable be without attaching to the surface?

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과목명 : 전자기학 **2017. 4.28. 시행**

2. [20 points] Consider a bendable string with fixed length $l = 2\pi R$ and mass M (with uniform mass density). An electric current I is flowing through the string with negligible resistance, and the string is rotating in a circular shape with angular velocity ω. [$\omega > 0$ denotes counter-clockwise rotation, when seeing the string from above, as shown in the figure. Also, $I > 0$ denotes counter-clockwise current in the same convention.] A uniform magnetic field $B > 0$ is applied, which is orthogonal to the plane on which the string rotates.

(a) [7 points] Compute the infinitesimal centripetal force ΔF acting on an infinitesimal element of the rotating circular string with length Δl. Also, compute the Lorentz force acting on the same element. (Ignore the magnetic field created by the current.)

(b) [8 points] When $I > 0$, show that the circular rotation is allowed for all ω. When $I < 0$, show that the circular rotation is allowed only for

$$I \geq -\frac{M\omega^2}{2\pi B} \ .$$

(c) [5 points] Consider a configuration of $\omega, I < 0, B > 0$ which saturates the inequality of (b). Then, suppose that one increases B. Would this change destabilize the circular motion or not?

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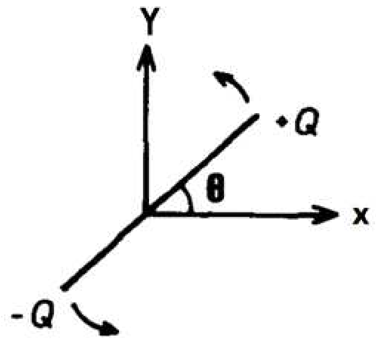
과목명 : 양자역학 **2017.04.28. 시행**

3. [27 points] A rod of length d and uniform mass distribution is pivoted at its center and constrained to rotate in a plane. The rod has mass M and charge +Q and −Q fixed at either end.



(a) [6 points] Describe this system quantum mechanically and find its Hamiltonian, eigenfunctions and their eigenvalues.

(b) [12 points] If a constant weak electric field E lying in the plane of rotation is applied to this system (x direction), what are the new eigenfunctions and energies to first order in E ?

(c) [9 points] If the applied electric field is very strong, how can you approximate the situation? Under your approximation, find an approximate wave function and energy for the ground state.

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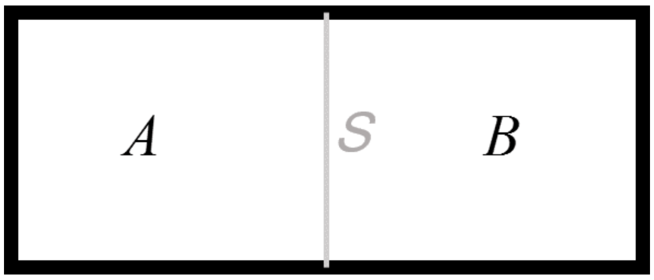
과목명 : 열 및 통계물리 2017.04.28. 시행

4. [13 points] Consider a container separated into two compartments (A and B) by a thin separating piston (S). Assume that initially the volumes of the two compartments are the same. Suppose that the entire system is thermally insulated from the environment.



Initially, A contains $3N$ molecules of a monatomic ideal gas at temperature T and B contains $2N$ molecules of the same ideal gas at temperature $2T$. (k_B is the Boltzmann constant.)

(a) [3 points] If S is thermally conducting but is fixed at the initial position, what will be the temperature of A and that of B after a long enough time?

For (b) and (c), assume that S is thermally conducting and is freely movable (to the left and to the right) from the initial position.

(b) [6 points] What will be (i) (1 pt) the temperature of B after a long enough time and (ii) (4 pts) the change in the entropy of the container (the entire system) in the meanwhile?

(c) [4 points] Suppose that we have waited for a long enough time so that the system has reached an equilibrium. Now suppose that S is suddenly removed from the system. What will be the change in the entropy of the entire system since the removal of S until after another long enough time has passed?

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과목명 : 실험 **2017.04.28. 시행**

5. [20 points] A tiny mirror is hanging from the rigid support by a thin quartz wire with a known torsional spring constant of k. That is, $\tau = -\kappa\theta$ where t is the torque required for the rotation of the quartz wire and θ is the angle of the mirror's torsional rotation with respect to the average angle $\theta = 0$.

(a) [7 points] How can one measure the ambient temperature using the mirror described above? State which physical quantity one needs to measure and describe how to make such measurements. (Hint: Consider the equipartition theorem. The ambient temperature is above 273K.)

(b) [6 points] Can the above measurement be affected by the ambient pressure? Explain.

(c) [7 points] Now consider a torsional oscillator consisting of a small container filled with the liquid ^{4}He supported by a thin quartz wire instead. It is known that below a certain low temperature, liquid ^{4}He starts to condense into a superfluid which can be regarded as a frictionless fluid (zero viscosity). How can one measure this normal fluid-superfluid transition temperature using such a torsional oscillator? Describe the necessary experimental set-up in as much detail as possible. (Hint: Forced oscillation, rotational inertia. A thermometer is provided.) Draw a schematic diagram if necessary.