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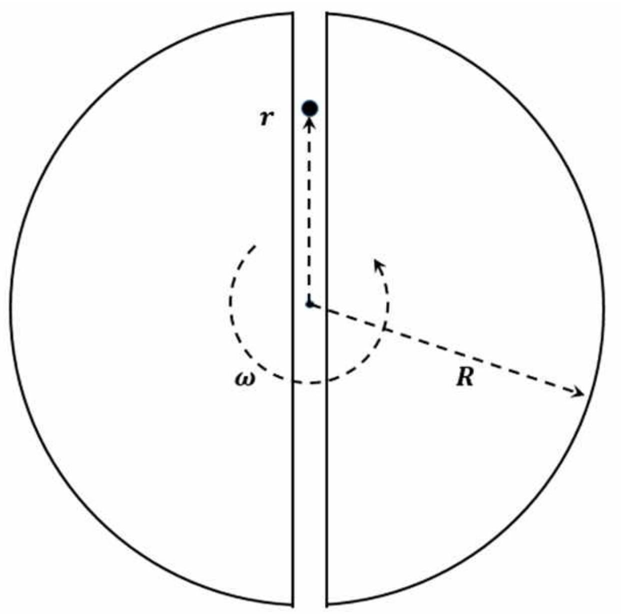
2018학년도 석사 및 석·박통합과정 후기모집 면접·구술고사 전공시험

과목명 : 고전역학 2018.05.01. 시행

1. A 3 dimensional sphere with radius R is uniformly charged with electric charge density $\rho > 0$. The sphere rotates along an axis passing through its center, with angular speed ω. There is a thin straight tunnel passing through the center, perpendicular to the rotation axis, as shown in the figure. Put a charged particle with mass m and electric charge $-e < 0$ in the hole, near the center of the sphere. Since the sphere and the tunnel rotate with constant angular speed, the particle's angular motion is constrained. [Ignore magnetic forces due to moving charges.]



(a) Show that the Lagrangian of the particle for its radial coordinate $r(t)$ is given by

$$L = \frac{1}{2}m\dot{r}^2 - \left(\frac{e\rho}{6\epsilon_0} - \frac{m\omega^2}{2}\right)r^2 \quad .$$

ϵ_0 is the vacuum permittivity. [5 points]

(b) For $\omega < \sqrt{\frac{e\rho}{3m\epsilon_0}}$, show that the particle with small initial speed makes a harmonic oscillation around $r=0$. [5 points]

(c) For $\omega > \sqrt{\frac{e\rho}{3m\epsilon_0}}$, put the particle slightly away from $r=0$ at zero initial speed. Compute the radial and angular components of the velocity as the particle reaches the surface $r=R$ of the sphere. [5 points]

(d) Again with the setting of problem (c), what is the minimal value of ω for which the particle can escape to $r=\infty$? [5 points]

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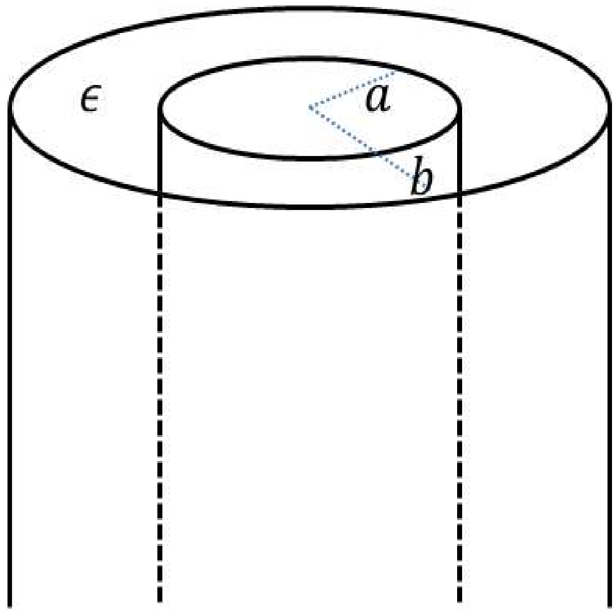
과목명 : 전자기학 **2018.05.01. 시행**

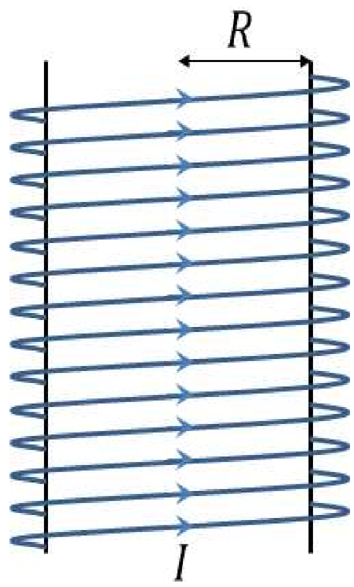
1. (8 pts) Consider an infinitely long coaxial cable composed of two thin metal cylinders with radii of a and b $(a < b)$, respectively. The space between the two cylinders is filled with material having dielectric constant (permittivity) ϵ.



(a) (4 pts) When the potential between the cylinders is V, find the electric field $\vec{E}$ between them.

(b) (4 pts) Calculate the capacitance per unit length of this system.

2. (12 pts) Consider an infinitely long solenoid consisting of n closely wound turns per unit length on a cylinder of radius R, carrying a steady current I.



(a) (6 pts) Find the magnetic field $\vec{B}$ and the vector potential $\vec{A}$ inside and outside the solenoid, respectively.

(b) (2 pts) Draw the magnetic field and the vector potential as a function of the distance from the axis.

(c) (4 pts) Calculate the inductance per unit length of the solenoid.

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과목명 : 양자역학 2018.05.01. 시행

1. Consider an electron (with the mass m and the electric charge $-e$) orbiting with momentum $\vec{p}$ around a much heavier nucleus (with the opposite charge Ze).

(a) (5pt) Write down the non-relativistic Hamiltonian of the electron, H_0, which is a sum of the kinetic energy and the electrostatic potential energy.

(b) (5pt) Now we consider relativistic effects. The electron moving in the static electric field $\vec{E}$ relativistically experiences a magnetic field

$$\vec{B} = -\vec{v} \times \vec{E}/c^2.$$

Express this magnetic field in terms of the electron's angular momentum $\vec{L} = \vec{r} \times \vec{p}$, where $\vec{r}$ is the radial vector of the orbit.

(c) (5pt) The electron has a magnetic moment $\vec{\mu} = -\frac{e}{m}\vec{S}$ due to its spin $\vec{S}$. Express the Hamiltonian H_1 of this magnetic moment in the magnetic field found in (b), in terms of the total angular momentum $\vec{J}^2 = (\vec{L} + \vec{S})^2$.

(d) (10pt) We define an eigenstate of $\vec{J}^2$ as

$$|j = \ell + 1/2\rangle = \alpha|\ell, m, 1/2\rangle + \beta|\ell, m+1, -1/2\rangle$$

with some real parameters α and β. The states on the right-hand side are denoted by $|\ell, m, s_z\rangle$ with angular quantum numbers ℓ and m and a spin quantum number $s_z = \pm 1/2$ defined as

$$\vec{L}^2|\ell, m, s_z\rangle = \ell(\ell+1)\hbar^2|\ell, m, s_z\rangle,$$

$$L_z|\ell, m, s_z\rangle = m\hbar|\ell, m, s_z\rangle,$$

$$\vec{S}^2|\ell, m, s_z\rangle = \frac{3}{4}\hbar^2|\ell, m, s_z\rangle,$$

$$S_z|\ell, m, s_z\rangle = s_z\hbar|\ell, m, s_z\rangle,$$

$$L_\pm|\ell, m, s_z\rangle = \sqrt{(\ell \mp m)(\ell \pm m + 1)}\,\hbar|\ell, m \pm 1, s_z\rangle,$$

$$S_\pm|\ell, m, s_z\rangle = \hbar|\ell, m, s_z \pm 1\rangle.$$

Find the conditions on α and β for $|j = \ell + 1/2\rangle$ to be the desired eigenstate.

(Hint: check whether $|j = \ell + 1/2\rangle$ is an eigenstate of $\vec{J}^2$ with $j = \ell + 1/2$.)

(e) (5pt) Finally, calculate the expectation value $\langle j = \ell + 1/2|H_1|j = \ell + 1/2\rangle$.

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과목명 : 열 및 통계 물리 **2018.05.01. 시행**

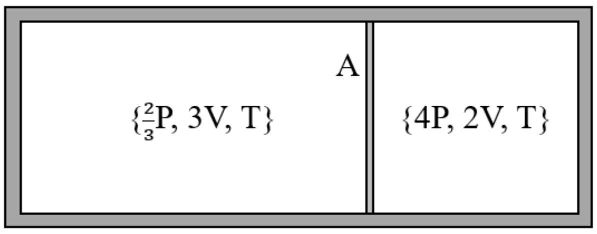
1. Consider one dimensional array of N particles. Each particle may be in one of the two energy states whose energies are 0 and ϵ, respectively. $\epsilon > 0$.

(a) Express the entropy $S(E)$ of the system when the total energy of the system is $E = n\epsilon$ $(0 \le n \le N)$. [2 pts]

(b) Sketch $S(E)$. Explain when the entropy S becomes maximum. Stirling's approximation is $\ln[x!] = x\ln[x] - x$ for large x. [3 pts]

(c) Describe the evolution of the system's temperature as E increases and explain how the system can have negative absolute temperature. [3 pts]

2. Consider a thermally isolated box with two compartments which are filled with ideal gases and separated by a thermally conducting partition A. The initial pressure, volume, and temperature of each section after gas filling are given as in the figure below. Then, we release the partition to move freely along the horizontal direction.



(a) Find the molar numbers of the gases contained in the two compartments. The gas constant is R. [2 pts]

(b) Find the final equilibrium temperature and pressure of the system. [2 pts]

(c) Calculate the increase of the total internal energy and the entropy of the system during the relaxation process. $\ln 2 \approx 0.7$ and $\ln 3 \approx 1.1$. [3 pts]

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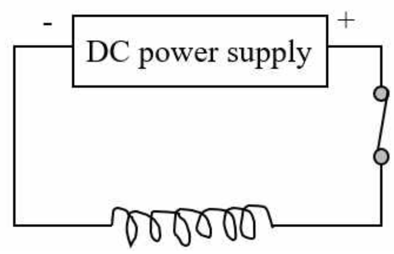
과목명 : 실험 **2018.05.01. 시행**

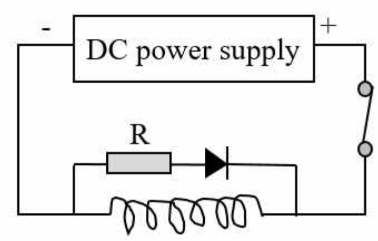
1. You have three DC power supplies A, B, and, C, whose voltage and current limits are specified as 18V-2A, 15V-8A, and 5V-10A, respectively. In the front panel of each power supply, you can control its voltage and current within its limits. Now, let's consider a situation where you have a 2-Ohm resistor and want to make a current of 8 A flow through the resistor. Explain how you can achieve this goal with the given three power supplies. [4 pts]

2. A coil of 10 Henry and 0.1 Ohm is connected to a DC power supply with a switch as in the following figure, and a current of 1000 A flows through the coil.



(a) When you suddenly open the switch, you may see a zap of sparks or arcing occur at the opening tip of the switch. Explain the reason. [3 pts]

(b) To prevent this minacious effect, you may connect a resistor and a diode around the coil as following. Explain how it would help. [4 pts]



(c) If you want to turn down the 1000-A current in the coil within a few ms, what is your choice for the resistance R? [4 pts]