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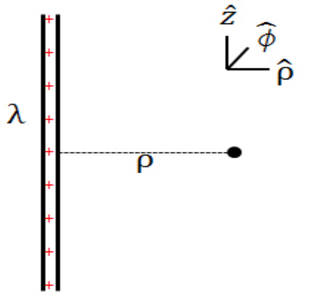
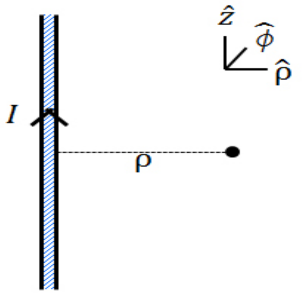
2013학년도 석사과정/석사박사통합과정
전기모집 면접·구술고사 전공시험

과목명 : 이론　　　　　　　　　　　　　　　　　2012. 11. 1 시행

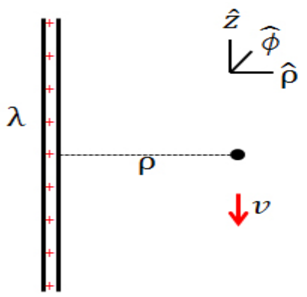
(a) (10 points) Show that an electric field generated by a uniform infinite line charge with the line charge density λ has the form of $\vec{E}=\frac{C_1(\lambda)}{\rho}\hat{\rho}$ and obtain $C_1(\lambda)$.



(b) (10 points) Show that a magnetic field generated by an infinitely long straight current I has the form of $\vec{B}=\frac{C_2(I)}{\rho}\hat{\phi}$ and obtain $C_2(I)$.

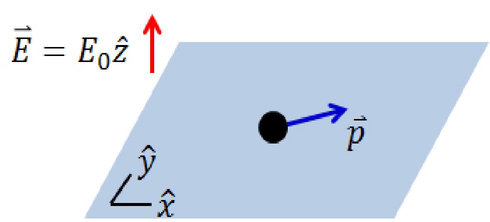


(c) (20 points) Imagine that in the case of (a), we are moving with a velocity $\vec{v}=-v\hat{z}$. Show that an effective magnetic field seen in this moving frame is approximately given by $\overrightarrow{B_{eff}}\approx C_3\vec{v}\times\vec{E}$ and obtain a constant C_3.



(d) (30 points) The spin-orbit interaction is the coupling between an electron spin and an effective magnetic field seen in the moving frame. Assume that the relation derived in (c) is in general true. Show that for a radial electric field $\vec{E}=E(r)\hat{r}$, the spin-orbit Hamiltonian has the following form, $H_{SO}=f(r)\vec{L}\cdot\vec{S}$ where $\vec{L}$ and $\vec{S}$ are the angular momentum and spin operators, respectively. For the angular momentum $l>0$ and spin $s=1/2$, find the energy splitting in units of the expectation value of the radial function $\langle f(r)\rangle$. (You do not need to derive the explicit form of $f(r)$.)

(e) (30 points) Consider a spin-1/2 particle moving in the two-dimensional space confined in the $\hat{x}-\hat{y}$ plane with the Hamiltonian $H_0=\frac{\vec{p}^{\,2}}{2m}$. When we apply a uniform electric field $\vec{E}=E_0\hat{z}$ along $\hat{z}$, show that the spin-orbit Hamiltonian has the following form, $H_{SO}=\alpha(\vec{\sigma}\times\vec{p})\cdot\hat{z}$ where $\vec{\sigma}$ represents Pauli matrices. Find the energy dispersion of the particle in the presence of the spin-orbit coupling. (You do not need to derive the explicit form of α.)



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Provide brief answers to the questions in Korean or in English.

2. Carbon atoms are unique in that they are able to form many different kinds of bonds with other carbon atoms. For example, graphite and diamond are composed of the carbon atoms. Graphite has a layered, planar structure in which the carbon atoms are arranged in a hexagonal lattice with separation of 0.142 nm in each layer and the distance between layers is 0.335 nm. And the carbon atoms in diamond are arranged in a three-dimensional tetrahedral structure in a variation of the face-centered cubic crystal structure. All bonds (carbon-carbon distance) are of the same length, 0.154 nm in diamond.

(a) The crystal structures of either graphite or diamond can be probed by experiments using the wave nature of photon, electron, or neutron beams. Briefly discuss the physical principle of such experimental techniques for studying the crystal structures of these materials.

(b) Make an order-of-magnitude estimate of the energy scale (in eV or Joule) of each case of photon, electron, and neutron beams, which can be used to study the crystal structures of these materials. Do not use an electronic calculator.
(Use the following values when needed: $h = 6.626 \times 10^{-34}$ Jsec, electron mass = 9.11×10^{-31} kg, neutron mass = 1.67×10^{-27} kg, speed of light = 3×10^{8} m/sec, 1 eV = 1.6×10^{-19} J.)

(c) The bonds between carbon atoms within the layers of graphite are strong, while the bonds between the layers are weak. The inter-layer coupling is so weak that the layers of carbon atoms can easily slide or be sliced. This is why graphite is used in pencil lead. Based on the structural characteristics of graphite, suggest an experimental method to produce graphene, i.e., one atomic layer of the carbon atoms arranged in a regular hexagonal pattern?

(d) In addition to the different crystal structures of graphite and diamond, other physical properties of the graphite and diamond are also quite different from each other. For example, graphite is a good electrical conductor but diamond is an insulator. Electrical conductivity (σ) is a quantity measuring a material's ability to conduct an electric current and expressed as $\sigma = ne\mu$, where n is charge (electron) density, e is the electronic charge, and μ is called mobility. Here, mobility is $\mu = e\tau/m$ (τ is the mean lift time, or mean scattering time of electron, i.e., average time duration between two consecutive scatterings). Experimentally there are several methods to measure n or μ. For example, four-probe measurement or Hall measurement are such methods. In particular, Hall measurement is a powerful experimental technique that can measure n and μ accurately. Now, briefly explain the physical principle of the Hall measurement. And, when one measures the electrical conductivity at a different temperature, briefly explain and compare the behavior of the electrical conductivity of graphite and diamond as a function of temperature.

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(e) In addition to different electrical properties, graphite is opaque in visible light while diamond is transparent in visible. Let's imagine that one shine the light (electromagnetic wave) of different frequency on these materials. <u>Compare the light absorption spectra</u> of graphite and diamond as a function of photon energy (Consider the range of photon energy less than 4 eV only). In addition, <u>discuss the difference</u> of their absorption spectra in terms of the quantum states of electrons in graphite and diamond, respectively.