PHY 491 - 2013

Atomic, Molecular, and Condensed Matter Physics

Problem Set 2

1. Two particles, with masses m_1 and m_2 and with charges e and $-e$, are confined to a plane. Assume that the center of mass is at rest and find the energy spectrum of this two-dimensional hydrogen-like system. (8 pt)

2. For a three-dimensional hydrogen atom in the ground state, find the probability to find the electron in a sphere centered at the origin (the position of the proton), with radius r (4 pt)

3. The magnetic moment of a charge distribution is given by the expression $\mathbf{m} = \frac{1}{2}\int dV \rho_q(\mathbf{r})\,[\mathbf{r}\times \mathbf{v}(\mathbf{r})]$, where $\rho_q(\mathbf{r})$ is the charge density and $\mathbf{v}(\mathbf{r})$ is the velocity. Assume that the charge density is proportional to the mass density $\rho(\mathbf{r})$, that is $\rho_q(\mathbf{r})/\rho(\mathbf{r}) = C$. Find the gyromagnetic ratio, that is, the ratio of the magnetic moment to the angular momentum (8 pt)

4. Calculate the paramagnetic susceptibility χ_N of N hydrogen atoms at room temperature ($k_B T \approx 0.025$ eV). Use that the operator of the magnetic moment of an individual spin is $\boldsymbol{\mu} = g\mu_B \mathbf{s}$. The magnetization $\mathbf{M}$ (magnetic dipole moment) is expressed in terms of the susceptibility χ_N as $\mathbf{M} = \chi_N \mathbf{H}$. Use that $s_x^2 = s_y^2 = s_z^2 = 1/4$. The standard quantities are susceptibility per unit volume, per unit mass, or per mole. (8 pt)

The solution is due on September 18. You need 20 points out of 28, the rest is extra credit