Modern Physics
Problem Set 13

JC-58) **Quantum Numbers for Hydrogen**
Explain why the following sets of quantum numbers (n, l, m_l, m_s) are not permitted for hydrogen.

a) (10 points) (2, 2, -1, +1/2)
b) (10 points) (3, 1, +2, -1/2)
c) (10 points) (4, 1, +1, -3/2)
d) (10 points) (2, -1, +1, +1/2)

JC-59) **Stern-Gerlach Revisited**
(20 points) Suppose the silver atoms in the Stern-Gerlach experiment traveled horizontally, first 1 m through the magnet and then after exiting the magnet, 1 m in a field-free region at a speed of 250 m/s. What must have been the gradient of B_z, dB_z/dz, in order that the beams each be deflected a maximum of 0.5 mm from the central position?

JC-60) **SWE for 2 Particles**
(10 points) Derive an expression for the energy of a two-particle system using the wave function given in equation 8-17 in your text. Assume particle 1 is in the n = 1 state and particle two is in the n = 2 state and that the potential is equal to zero (U = 0).

JC-61) **Electrons and Pions**
Five identical noninteracting particles are placed in an infinite square well with L = 1.0 nm. Compare the lowest total energy for the system if the particles are

a) (10 points) electrons.
b) (10 points) pions. Pions have symmetric wave functions and their mass is 264 m_e.

JC-62) **The 21 cm Line**
One of the most important windows to the mysteries of the cosmos is the *21 cm line*. With it, astronomers map hydrogen (important in star formation) throughout the universe. An important trait is that it involves a highly forbidden transition that is quite long-lived. It is an excellent example of the coupling of angular momenta. Hydrogen's ground state has no spin-orbit interaction. For $l = 0$, there is no orbit. However, the proton and electron magnetic moments do interact.

Consider the following model.

a) (10 points) The proton sees itself surrounded by a spherically symmetric cloud of *1s* electron, which has an intrinsic magnetic dipole moment/spin that has a direction. For the purpose of investigating its effect on the proton, treat this dispersed magnetic moment as behaving effectively like a single loop of current whose radius is a_0. Then find the magnetic field at the middle of the loop in terms of e, $\hbar$, m_e, μ_0, and a_0.
b) (10 points) The proton sits right in the middle of the electron's magnetic moment. Like the electron, the proton is a spin-1/2 particle, with only two possible orientations in a magnetic field. Noting, however, that its spin and magnetic moment are parallel, rather than opposite, would the interaction energy be lower with the proton's spin aligned or anti-aligned with that of the electron?
c) (10 points) For the proton, g_p, is 5.6. Obtain a rough value for the energy difference between the two orientations.
d) (10 points) What would be the wavelength of a photon that carries away this energy difference?

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Talk) **FINAL DRAFT DUE MONDAY NOVEMBER 20 AT 3 PM.**
(0 points) Email your pdf to cooley@physics.smu.edu before due date. If your talk is late less than one hour, your maximum grade will drop one increment (i.e. A —> A-). If your talk is late 1 - 2 hours, your maximum grade drops two increments (A —> B+) and so on.