Phys 512 Prof. P. Berman
Quantum Mechanics II Winter, 2004

Problem Set 1
Due Friday, January 16

1. Problem 84.

2. Use simple arguments based on the uncertainty principle to show that it would be impossible to determine the magnetic moment of a free electron by measuring the magnetic field associated with the electron. In a similar manner it is not possible to measure the magnetic moment of a free electron in a standard Stern-Gerlach experiment (you are not asked to prove this, but would need to use the fact that $\nabla \cdot \mathbf{B} = 0$ and show that the Lorentz force on the charged electron is always greater than the splitting of the beam). However it may be possible to measure such splitting using a longitudinal Stern-Gerlach type experiment - see G. Gallup, H. Batelaan, and T. Gay, Phys. Rev. Lett. **86**, 4508 (2001).

3. Find the eigenfunctions and eigenenergies for a free, nonrelativistic electron moving in a constant external magnetic field. For a given center-of-mass energy, find the splitting of the energy levels of the spin up and spin down states and express your answer in units of MHz/Gauss.

4. Calculate the magnetic moment of the electron, assuming it is a uniformly charged sphere. What rotation rates would be necessary to produce the observed magnetic moment?

5. For the problem discussed in class in the resonance approximation for which we obtained equations of motion

$$\frac{d\tilde{a}}{dt} = -i\frac{\delta}{2}\tilde{a} - i\frac{\omega_x}{2}\tilde{b};$$
$$\frac{d\tilde{b}}{dt} = +i\frac{\delta}{2}\tilde{b} - i\frac{\omega_x}{2}\tilde{a},$$

obtain a solution for $\tilde{a}(t), \tilde{b}(t)$, given initial conditions $\tilde{a}(0), \tilde{b}(0)$. For $\tilde{a}(0) = 1, \tilde{b}(0) = 0$, plot $\left|\tilde{b}(t)\right|^2$ vs $\omega_x t$ for $\delta/\omega_x = 0, 1, 10$.