Due: Tuesday, 03/15

15. Starting with a calculation of the ground-state hyperfine-structure interval in hydrogen (see, for example, Atomic Physics: an exploration in problems and solutions, Problem 1.4), calculate the ground-state hyperfine-structure intervals for:

a. The $^3He^+$ ion
b. Muonium (μ^+e^-)
c. Muonic hydrogen (μ^-p)
d. Positronium (e^+e^-)

Compare your results with the experimental values for the interval $[E(F=1)- E(F=0)]/h$ equal to -8.66 GHz ($^3He^+$), +4.46 GHz (muonium), +203 GHz (positronium). The ground-state hyperfine interval for Muonic hydrogen has not as yet been measured. Do your predictions agree with the experiment? If not, what kind of physics that has not been taken into account may be contributing to the discrepancy?

A modern reference on precision spectroscopy in hydrogen and other hydrogenic systems for further reading is: The Hydrogen Atom: Precision Physics of Simple Atomic Systems (Lecture Notes in Physics, 570)
Ed. by S. G. Karshenboim, F. S. Pavone, F. Bassani, M. Inguscio, T. W. Hansch
Springer-Verlag Telos; Bk&CD-Rom edition (2001); ISBN: 3540419357

16. Nowadays, it is not unreasonable to think about experiments on board spacecraft. Suppose a magnet producing a uniform magnetic field in a certain region between its poles freely floats within a spacecraft. An ensemble of unpolarized paramagnetic atoms is placed in the magnetic field. At t=0, a short pulse of circularly-polarized light propagating perpendicularly to the magnetic field illuminates the atoms, and some of the photons are absorbed transferring angular momentum to the atoms. Atoms in the excited state quickly decay to the ground state, so the result is long-lived ground-state atomic polarization (optical pumping; see, for example, Ch. 3 of Atomic Physics: an exploration in problems and solutions). Now, the angular momentum of the atomic sample oriented perpendicular to the magnetic field undergoes Larmor precession.

Explain how angular momentum is conserved during this precession. Describe the motion of the magnet assuming that its moment of inertia is a diagonal tensor.