1. (Merzbacher Exercise 17.32.) Prove from the Wigner-Eckart theorem and the special case Clebsch-Gordan coefficients given in Merzbacher Eq.(17.62), that the reduced matrix of $\vec{J}$ is
$$\langle \alpha j' || \vec{J} || \alpha j \rangle = \sqrt{j(j+1)}\hbar\delta_{jj'}$$

2. (Merzbacher Problem 17.6.) The magnetic moment operator for a nucleon of mass m_n is $\vec{\mu} = e(g_\ell \vec{L} + g_s \vec{S})/2m_n c$, where $g_\ell = 1$ and $g_s = 5.587$ for a proton, and $g_\ell = 0$ and $g_s = -3.826$ for a neutron. In a central field with an additional spin-orbit interaction, the nucleons move in shells characterized by the quantum numbers ℓ and $j = \ell \pm 1/2$. Calculate the magnetic moment of a single nucleon as a function of j for the two kinds of nucleons, distinguishing the two cases $j = \ell + 1/2$ and $j = \ell - 1/2$. Plot j times the effective gyromagnetic ratio versus j, connecting in each case the points by straight-line segments. (These are called *Schmidt lines.*)

3. Use first order perturbation theory to estimate the effect of the finite size of the proton on the ground state energy level of the hydrogen atom. Assume the proton is a uniformly charged sphere of radius R, and consider the difference between the potential energy in this model, and the idealized potential. Find a value for the proton radius, the size of this energy shift, and compare it to the size of the spin-orbit splitting.

4. (See Sakurai Problem 5.28.) A collection of hydrogen atoms in the ground state are in between the plates of a parallel plate capacitor. The capacitor is turned on suddenly at time $t_0 = 0$, leading to an electric field $\mathcal{E}(t) = \mathcal{E}_0 e^{-t/\tau}$.

   a. The transition probabilities to which of the various $n = 2$ final states will be nonzero as $t \to \infty$. Explain your reasoning. Calculate the transition probability for any final states for which the result may be nonzero. (I suggest that you use MAPLE for the radial integrals.)

   c. Take the appropriate limits for $\mathcal{E}_0$ and for τ so that the voltage pulse is a δ-function. Discuss the resulting transition probability(ies).

5. (Merzbacher Exercise 19.10.) Deduce the selection rule for autoionizing transitions from a $2s\ np$ initial to a $1s\ kl$ final state. Do the same for transitions from $(2p)^2$ to $1s\ kl$. Identify the terms in the multipole expansion of the electron-electron Coulomb interation that are responsible for the transitions.

6. (Merzbacher Problem 19.2.) Calculate the total cross section for photoemission from the K shell as a function of the frequency of the incident light and the frequency of the K-shell absorption edge, assuming that $\hbar\omega$ is much larger than the ionization potential but that nevertheless the photon momentum is much less than the momentum of the ejected electron. Use a hydrogenic wave function for the K shell and plane waves for the continuum states.