1. Consider the decay of a $3d$ state of hydrogen atom to the $2p$ level.
   (a) If the initial state has $m = 2$, show that the only possible final state is $m = 1$.
   (b) Calculate the decay rate for this transition.
   (c) Compare it to the data ($A_{ki}$ in "Persistent Lines of Neutral Hydrogen" at NIST web site, and discuss why it agrees with one but not the other entry.

2. Calculate the cross section of the scattering of a photon off an electron in the following steps (basically the time-dependent treatment in the scattering theory). Assume that the photon energy is much smaller than $m_e c^2$ (non-relativistic).
   (a) Using expressions in the lecture notes for the photon-atom scattering before the dipole approximation is made, and take the initial, final, and intermediate electron states to be plane waves $\langle x|A \rangle = L^{-3/2} e^{i\vec{p}_i \cdot \vec{x}/\hbar}$, $\langle x|B \rangle = L^{-3/2} e^{i\vec{p}_f \cdot \vec{x}/\hbar}$, and $\langle x|I \rangle = L^{-3/2} e^{i\vec{k} \cdot \vec{x}/\hbar}$. Perform the space integral and obtain the amplitude.
   (b) With $\vec{p}_i = 0$, show that the terms due to the second-order perturbation vanish, and that the amplitude is given by
   \[
   \langle f|U_I|i \rangle = -i 2\pi \delta(E_f - E_i) r_0 \frac{2\pi \hbar c^2}{L^6} \frac{1}{\sqrt{\omega_i \omega_f}} (2\pi \hbar)^3 \delta(\vec{p}_i + \vec{q}_i - \vec{p}_f - \vec{q}_f) \hat{e}_f^* \cdot \hat{e}_i.
   \] (1)
   (c) Using the usual trick to rewrite one factor of $2\pi \delta(E_f - E_i) = T/\hbar$, and similarly $(2\pi \hbar)^3 \delta(\vec{p}_i + \vec{q}_i - \vec{p}_f - \vec{q}_f) = L^3$, find the expression for the cross section. Show that it agrees with the classical Thomson scattering cross section.
   (d) Make a rough estimate on how long a photon created at the core of the Sun takes to diffuse out of it.

3. Using the shell model, calculate the magnetic moments of the nuclides $^{209}$Pb, $^{207}$Pb, $^{209}$Bi, and $^{207}$Tl. Compare them to the observed values $-1.44 \mu_N$, $+0.578 \mu_N$, $+4.11 \mu_N$, and $+1.88 \mu_N$. (The agreement is not perfect.)