MASSACHUSETTS INSTITUTE OF TECHNOLOGY

**5.74 Quantum Mechanics II**
**Spring, 2004**

Professor Robert W. Field

*Problem Set # 6*

**DUE:** At the start of Lecture on Monday, April 12.

**Reading:** HLB–RWF 9.1.3, 9.1.4, 9.1.7.

**Problems:**

1. Return to problem 1D of Problem Set #5. Use spherical tensor algebra and the Wigner-Eckart Theorem to compute the relative transition amplitudes for all of the allowed $n'p \leftarrow 6s$ transitions from $J = 3$, $M_J = 2$ of $6s5d\ ^3\text{D}_3$ into the various $L$-$S$-$J$-$M_J$ states of the $n'p5d$ configuration. The transition moment operator is of the $\mathbf{T}^1(q_1)$ form where $q_1$ refers to the position coordinate of electron 1. Your $L$-$S$-$J$-$M_J$ states are coupled with respect to $L$ and$S$ and with respect to electron 1 and electron 2.

2. Return to problem 2 of Problem Set #5. Use spherical tensor algebra to relate $\zeta(N, L, S)$ and $C(N, L, S, J)$ for the $^1\text{P}_1$ and $^3\text{P}_J$ states of $6snp$ and the $^1\text{D}_2$ and $^3\text{D}_J$ states of $6s5d$ of $^{137}\text{Ba}$ to the single-orbital parameters $\zeta_{np}$, $\zeta_{5d}$, $a_{6s}$, $a_{np}$, $a_{5d}$, $b_{6s}$ $b_{np}$ and $b_{5d}$. The single-orbital parameters are most "fundamental" because they are transferable from one state to another and are even scalable as a function of quantum number $n$ and nuclear charge (isoelectronic series).

3. Return to problem 2C of Problem Set #5. Use spherical tensor techniques to compute the relative transition amplitudes into the fine, hyperfine components of $6snp\ ^3\text{P}_J$ from the various hyperfine components of $6s5d\ ^3\text{D}_J$ $J = 3$ and $J = 2$.

4. Return to problem 2D of Problem Set #5. Let

$$\begin{aligned}
\zeta_{np} &= (6/n)^3 \zeta_{6p} \\
\zeta_{6p} &= 832 \text{ cm}^{-1} \\
a_{6s} &= 0 \\
a_{np} &= 10^{-3} \zeta_{np} \\
b_{6s} &= 1 \text{ cm}^{-1} \\
b_{np} &= 0
\end{aligned}$$

Find the 3 values of $n$ for which $\zeta_{np} = 10\, b_{6s}$, $\zeta_{np} = b_{6s}$, and $\zeta_{np} = 0.1\, b_{6s}$. Compute the level structure, transition amplitudes, and quantum beating signal for pulsed excitation from $6s5d\ ^3\text{D}_J$ ($J = 3$ and $J = 2$) to $6snp\ ^3\text{P}$. [Ignore the effects of $^1\text{P}_1 \sim {}^3\text{P}_1$ spin-orbit interactions.]