1. A particle in a two dimensional box of sides a. If a perturbation

$$V' = \lambda xy$$

is applied, find the change in the energy of the ground state and the first excited state.

2. A rotator whose orientation is specified by the angular coordinates θ and ϕ performs a *hindered rotation* described by the Hamiltonian

$$H = A\mathbf{L}^2 + B\hbar^2 \cos 2\phi$$

with $A >> B$. Calculate the S, P and D energy levels of this system in the first order perturbation theory, and work out unperturbed energy eigenfunctions.

3. For a particle of mass m moving in the potential

$$V = \frac{1}{2}kx^2 + \frac{1}{2}ky^2 + \lambda xy$$

Find the approximate expressions for energy of the ground state and the first excited state.

4. A particle of mass m and a charge q is placed in a box of sides (a, a, b), where $b < a$. A weak electric field

$$\vec{E} = \mathcal{E}(y/a, x/a, 0)$$

is applied. Find the energy of the ground state and the first excited state.

5. Find the shift in the ground state energy of a 3D harmonic oscillator due to relativistic correction to the kinetic energy.

6. If the general form of a spin-orbit coupling for a particle of mass m and spin $\mathbf{S}$ moving in a central potential $V(r)$ is

$$H_{SO} = \frac{1}{2m^2c^2}\mathbf{S}\cdot\mathbf{L}\frac{1}{r}\frac{dV(r)}{dr},$$

what is the effect of the coupling on the spectrum of 3D harmonic oscillator?