37. A particle of mass m and charge q moves in a magnetic field $\mathbf{B} = B\,\mathbf{e}_z$. Determine the energy eigenvalues and the corresponding eigenvectors.

    Hint: Express the Hamiltonian using the conjugate momenta Π_x and Π_y. Determine the commutator relations of these momentum operators. Now introduce ladder operators like you did for the harmonic oscillator.

38. A spin $s = \frac{3}{2}$ is determined by a state $|\chi\rangle$, which possesses the expectation value $+\frac{\hbar}{2}$ for the z-component of the spin.

    a. Can we conclude, thet the vector $|\chi\rangle$ has to be the eigenvector of S_z?

    b. Will the conclusion of (a.) be changed, if we assume additionally, that expectation values of S_x and S_y are zero in the state $|\chi\rangle$?

39. A electron is located in the magnetic field $\vec{B}$, which is given by his vector potential $\vec{A}$.

    a. How does the time-dependent Schrödinger equation look like for the 2-component state function $\hat{\psi}(\vec{r}, t)$ of the electron in the $\{\vec{r}m_s\}$-representation?

    b. Show for homogenous magnetic fields, that the dynamics of the spin can be separated from the dynamics of the 'path movement' by the ansatz

    $$\hat{\psi}(\vec{r}, t) = \left[\begin{array}{c} \psi(\vec{r}+, t) \\ \psi(\vec{r}-, t) \end{array} \right] = \phi(\vec{r}, t)\hat{\chi}(t), \qquad \hat{\chi}(t) \left[\begin{array}{c} \chi(+, t) \\ \chi(-, t) \end{array} \right]$$

    Describe the equations of motion ofr the state function $\phi(\vec{r}, t)$ and the spinor $\hat{\chi}(t)$.

40. Consider a system of two spins with $S_1 = S_2 = \frac{1}{2}$. The state space in the $|S_{1z}, S_{2z}\rangle$-representation is $\{| + +\rangle, | + -\rangle, | - +\rangle, | - -\rangle\}$. In the $|S, S_z\rangle$-representation (total spin $\vec{S} = \vec{S_1} + \vec{S_2}$) there are three triplett-state with $S = 1$ ans one singulett-state with $S = 0$. What will arise for the singulett- and triplett-state with $S_z = 0$ if we change to the $|S_{1x}, S_{2x}\rangle$-representation?