Section A. Quantum Mechanics

1. **Hyperfine Structure**

The hyperfine structure of the $n = 1$ level of the hydrogen atom arises from a coupling between the electron spin $\mathbf{S}_e$ and the proton spin $\mathbf{S}_p$ with Hamiltonian

$$H = A\mathbf{S}_e \cdot \mathbf{S}_p \ ,$$

where A is a positive constant. Use the convention where the spin operators are dimensionless. The kinetic energy and Coulomb interaction do not lift the spin degeneracies and may be ignored in this problem.

(a) What are the energies and degeneracies of the hyperfine levels in the absence of a magnetic field?

A uniform magnetic field $\mathbf{B}$ is turned on for a period of time. Assume that the field is constant for $0 < t < T$ and zero for all other times.

(b) To a good approximation you can ignore the coupling of the proton spin to the magnetic field, compared to that of the electron spin. Briefly explain why this is true.

(c) Assume the atom was in the hyperfine state with total spin zero for $t < 0$. What is the probability that it remains in this state for $t > T$?