M09Q.1 - Hydrogen Beam (J94Q.1)

Problem

A beam of hydrogen atoms in in the lowest hyperfine level of the $1s$ state. The beam particles enter and pass through a region of space in which there is a uniform magnetic field of strength $B = 100$ gauss. The particles move with a spread of velocities such that the time they spend in the magnetic field is distributed uniformly between 1 and 2 seconds. Treating the magnetic field effect as a small perturbation, compute to lowest order the fraction of atoms that are in the upper hyperfine level as they exit the magnetic field. A numerical answer is wanted.

Remarks:

The proton magnetic moment is negligibly small compared to that of the electron. For the electron, the Bohr magneton is $e\hbar/2m_e c \approx 5.9 \times 10^{-9}$ eV/gauss.

The hyperfine wavelength (i.e. the wavelength of radiation emitted when the atom jumps from the upper to the lower hyperfine level) is $\lambda = 21$ cm.

Planck's constant (divided by 2π) is: $\hbar \approx 6.58 \times 10^{-16}$ eV s.