BE-1
August 2011 QE

Part I: Basics of NMRI [50 points]

(1) (10 pts) Write the Larmor Equation. Define all terms.

(2) (20 pts) Briefly describe the physical meaning of each of the T_1 and T_2. Include in your answer some examples of the properties of a material that may lead to a long or short value of each.

(3) (10 pts) What is the T_2^* time-constant? and how does this affect efforts to quantify T_1 and/or T_2?

(4) (10 pts) Many NMR systems to do not use a circularly polarized radio-frequency field for excitation. Rather, they use a field that oscillates (sinusoidally) along a cardinal axis of interest (i.e., $\hat{x}$, $\hat{y}$ or $\hat{z}$). What is the efficiency of this approach relative to the ideal circularly polarized field, with regard to tipping a spin away from the z-axis?

Part II: NMRI Experimentation [50 points]

For questions **(5)**–**(7)**, consider a (finite) object having proton density $\rho(x,y)$ such that $\int_x \int_y \rho(x,y)\ dx\ dy = S_0$. Assume that the relaxation times and magnetic environment of the object are spatially uniform — i.e., $T_1(x,y) = T_1$, $T_2(x,y) = T_2$, $\omega_0(x,y) = \gamma B_0(x,y) = \gamma B_0 = \omega_0$, with γ corresponding to the gyromagnetic ratio of the nucleus being investigated. *Note:* We will ignore T_2^* in this problem.

(5) (15 points) At $t = 0$, a 90 degree radio frequency (RF) tip is applied (uniformly) to the object to bring the magnetization vectors into the transverse plane. Provide an equation for the received free induction decay (FID) signal as a function of time, $S(t)$.

(6) (15 points) Now a two-pulse (saturation recovery) experiment is conducted beginning with a 90 degree RF tip at $t = 0$, followed by a second 90 degree RF tip at $t = t_s^-$. What is the amplitude of the transverse magnetization signal (i.e., that along the x-axis) measured at $t = t_s^+$?

(7) (20 points) The same experiment as in **(6)** is conducted, but using an α degree RF time at $t = t_s$. Provide an equation for the FID signal (transverse magnetization) observed subsequent to this 2nd tip — i.e., provide an equation for $S(t), t > t_s$.