Homework #1
MRI Physics

Due date: 2/5/2013

(1) (10 points) In your own words, explain the difference between *TE* and *TR*.

TE and TR are parameters controlled by the experimenters.

TE = time of echo = between the time of RF excitation and the time of data acquisition (more precisely, the time at the center of k space).

TR = time of repetition = time period to excite the same spins again.

(2) (10 points) In your own words, explain the difference between T_1, T_2 and T_2*.

T1, T2 and T2* are the properties of the tissue.

T1 = time constant that characterizes the recovery of the longitudinal magnetization after excitation by an RF pulse.
T2 = time constant that characterizes the spin dephasing in the transverse plane after excitation by an RF pulse (starting with 0 dephasing)

$$S = kM_0(1 - e^{-\frac{TR}{T_1}})e^{-\frac{TE}{T_2}}$$

When TR = T1, 1-exp(-TR/T1) = 1- exp(-1) = 0.632
When TE = T2, exp(-TE/T2) = exp(-1) = 0.368

T2* = T2 under the effect of magnetic field inhomogeneity.

(3) (10 points) In your own words, explain how magnetic field gradients are used in selecting the slice of tissue to image and allowing us to image different locations of this slice.

A slice of tissue is selected with an excitation RF pulse with a user-defined bandwidth along with a slice-select gradient. The slice-select gradient (or typically called the Z gradient) introduces a range of Larmor frequency.

After the slice is selected in the Z direction, a gradient can be applied in the X or Y direction to encode the pixel locations. Different locations have different Larmor frequencies, and thus different amounts of phase accumulations after a gradient is applied for a period of time.

(4) (10 points) What is the difference between laboratory and rotating frames in our 3T scanner?

Laboratory = you are the reference.

Rotating frame = the spins rotating at the Larmor frequence is the reference, rotating at 128 MHz at 3T.

(5) (10 points) In your own words, explain what *k* space, Bloch Equation and EPI are.

K space = raw data in the spatial frequency domain. 0 frequency at center of K space. Image is formed after inverse Fourier transformation.

Block Equation = equation to describe the magnetization.

EPI = fast imaging technique, characterized by fast gradient switching. All data for one image is acquired after one RF excitation.

(6) (10 points) In your own words, explain the difference between gradient echo and spin echo techniques.

Gradient echo = measure T2* effect.
Spin echo = measure T2 effect. Use 180 degree RF pulse to refocus the spins to reduce the field inhomogeneity effect. The spin-spin interaction could not be removed with the 180 degree RF pulse.

(7) (10 points) Calculate the Larmor frequency in an 9.4 T MRI scanner.

$\omega = \gamma$ B = (42.58 MHz/T) x 9.4T = 400 MHz
or
= (2.67 x 10^8 radian/sec/T) x 9.4 T = 2.51 x 10^9 radian/sec.

(8) (30 points) I had two tissue types. Tissue 1 had a T_1 = 1.4 sec and T_2* = 60 ms. Tissue 2 had T_1 = 700 ms, and T_2* = 30 ms. I ran a gradient echo scan with 90 degree flip angle. Assuming they contained about the same amount of tissue water, the same magnetization and hardware scaling factors, please predict the MR signal ratio between these two tissue types if I chose

(a) *TR* = 3 sec, and *TE* = 50 ms.
(b) *TR* = 3 sec, and *TE* = 6 ms.
(c) *TR* = 1000 ms, and *TE* = 6 ms.

Please show the details of your calculation.
Equation to use:

$$S = kM_0(1 - e^{-\frac{TR}{T_1}})e^{-\frac{TE}{T_2*}}$$

Signal ratio between Tissue 1 and Tissue 2 will be:
(a) 2.06
(b) 0.989
(c) 0.742