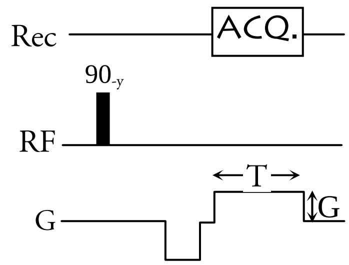
MRI Primer, Exercise #9 (last one!)
Due 2/Feb/2010

1. **SNR Dependence on Imaging Parameters**. You'd like to image a 1D object having a FOV of 20 cm using a simple 1D gradient-echo based sequence:



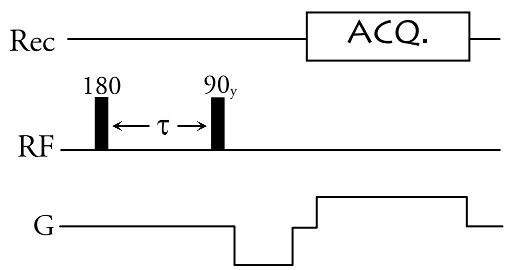
Assume N points are acquired, with a dwell time δt.

   a. How would doubling the gradient while keeping all other parameters (N, T, δt) fixed affect the SNR? How would it affect the voxel size and FOV?
   b. How would doubling T and, consequently, N (while keeping all other parameters fixed) affect the SNR, voxel size and FOV?
   c. The SNR expression derived in class does not depend on the FOV. Is that really true? In other words, suppose you wanted to double the FOV, while keeping the voxel size fixed. How would the SNR change, if at all?

2. **Increasing the Signal?** John wishes to run a 1D imaging experiment on a material having $T_1=\infty$. He has an ingenious idea how to make better use of the magnetization at his disposal. Instead of exciting it with a 90_{-y} hard pulse and doing a gradient-echo sequence (like the one shown in question #1), he decides to (a.) use a 45_{-y} pulse, acquire in the presence of a gradient, wait for the transverse magnetization to die away due to T_2 relaxation, and then (b.) make use of whatever magnetization is left along the z-axis by giving a 90_{-y} pulse and acquiring once again. Each experiment, he reasons, would tilt $\cos\left(45^\circ\right)=\frac{1}{\sqrt{2}}$ of the magnetization onto the xy plane. Adding up the two results should increase the overall signal by a factor of $2\times\frac{1}{\sqrt{2}}=\sqrt{2}$. He describes his idea to Prof. Slichter, his PhD advisor. Was the professor as enthusiastic as his student?

3. **Mapping T_1**. You're given an arbitrary body with some spatial distribution of $M_0(\mathbf{r})$, $T_1(\mathbf{r})$ and $T_2(\mathbf{r})$. Devise a method for getting a map of T_1 as a function of position using spin and/or gradient echo imaging (or both, if you feel). You may use more than one experiment (i.e. acquire more than one image, using different TE, TR, flip angle, etc).

4. **More Water Suppression**. Here is a technique for suppressing water which relies on the T_1 value of water being different from the T_1 value of whatever it is you're trying to see (fat, other metabolites, etc). Consider the following 1D gradient echo imaging pulse sequence:



   a. Starting from thermal equilibrium, $\mathbf{M}=M_0\mathbf{z}$, where would the magnetization, $\mathbf{M}$, point after the 180 pulse?
   b. Write down $\mathbf{M}$ after a time τ, just before the 90_y pulse. Hint: make use of problem 2 in exercise 3. Treat T_1 as a parameter.
   c. Write down M_{xy}, the transverse magnetization, right after the 90_y pulse.
   d. Based on parts (a-c), how would you choose τ to make M_{xy} vanish, assuming you know T_1? What would its value be for, say, T_1=1000 ms (this roughly corresponds to grey matter in the brain)?

Good luck!