1. a) In typical proton NMR imaging experiments, RF pulse lengths (\(\phi_{\text{tip}} = 90^\circ\)) are 1000 \(\mu\text{sec}\). How big is \(B_1\)? How does this compare to typical values for \(B_0\)?
b) For a 4 turn solenoid of radius 20cm, what current would need to be applied to generate this field? Estimate the power needed to apply this current.
c) If \(B_0 = 1.5\text{T}\), and the RF pulse is applied 5 kHz off resonance at the strength given in part (a), what is \(B_{\text{eff}}\)? Where would the magnetization vector point after the 1000 \(\mu\text{sec}\) ‘90°’ RF pulse? Is this a true 90° pulse?

2. a) If you were to perform an equivalent of the basic NMR experiment on a free electron (a.k.a. an ESR or electron spin resonance experiment), what would be the resonance frequency at 1.5T? Is this a practical experiment? What limitations might there be for doing this in humans?
b) What field strength would you need to produce the same electron resonance frequency as you get from a proton NMR experiment?
c) What \(B_1\) field strength would you need to apply to obtain a 90° RF pulse in 10 \(\mu\text{sec}\)?

3. a) The Martinos Center has built and now operates a human-sized 7.0T MR imaging system. If \(B_0 = 7.0\text{T}\) and the nuclei of interest are protons, what is the ratio of parallel to anti-parallel spins at room temperature? How does this compare to our current 1.5T and 3.0T imaging systems? How do these values change if the nuclei of interest are carbon-13 instead?
b) Not convinced that this is enough of a difference in the spin states, you set out to explore two possibilities for improving the net magnetization available. You have two options: temperature or a further increase in field strength.
   i) For protons, at what temperature can you get a 2-1 ratio of low to high energy spins at this field strength? For \(^{13}\text{C}\)?
   ii) For protons, what field strength would you need to achieve this differential at room temperature? For \(^{13}\text{C}\)?