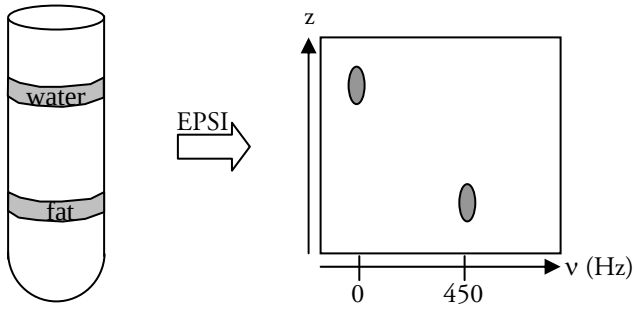
MRI Primer, Exercise #8
Due 26/Jan/2009

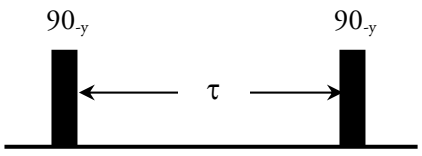
Question 1.
This is really an open question, as there are many ways of distinguishing the two compartments. Here are a couple of ideas:

- Use a selective excitation pulse **without** gradients, centered around 0 Hz (the water resonance), and with a duration T such that 1/T<450 Hz. This ensures the fat peak does not get excited. Following this selective pulse, do a simple 1D imaging experiment. You will get a signal just from the compartment containing the water. The remaining compartment must therefore contain the fat.
- Excite and use a fat suppression technique, as discussed in question 2.
- Here is another idea: excite both species, but wait a time $t>>T_2$ of the fat but $t\sim T_2$ of the water (say, ~100 ms in this question). This would "kill off" the fat and, once again, a simple 1D imaging experiment will give just the water image.

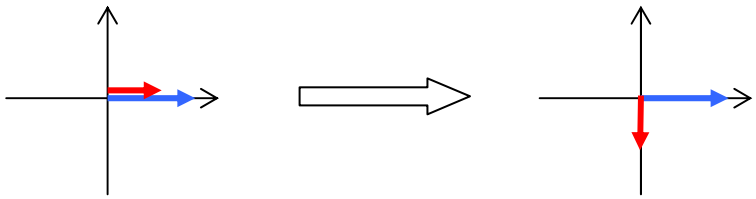
The "proper" way of doing this in a single scan would be to do chemical shift imaging (e.g., EPSI, as described in Lucio's lecture notes). This would give you a 2D "image", one axis of which is spatial and the other spectral. For example, for



Question 2.
Here is the pulse sequence:



The idea is to excite both spins (water and fat) with the first pulse, and then to wait enough time until they are 90 degrees apart, after which a second pulse would be used to store one and not the other. For example:



xy-plane, after 1st pulse (blue: water, red: fat)

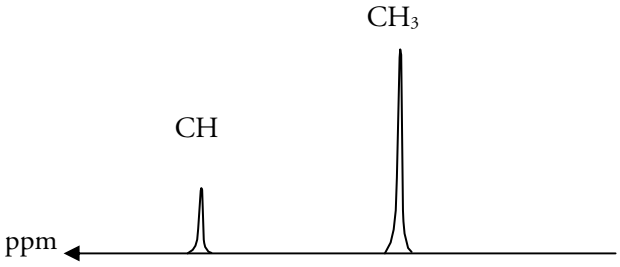
after a time τ, before 2nd pulse

The amount of time you'd have to wait would be the amount of time it would take the fat to precess by 90 degrees about the z-axis (the water doesn't move, it's on resonance):

$$2\pi \times 450\text{Hz} \times \tau = \frac{\pi}{2} \qquad \Rightarrow \qquad \tau \approx 0.55 \text{ msec}$$

The second pulse, given about the y-axis, will affect only the water and store it along the z-axis, thus suppressing its signal and leaving just the fat in the xy-plane.
In practice, there are several reasons not to use this sequence. The first is that there isn't a single resonance frequency of water or a single resonance frequency of fat. Due to magnet inhomogeneity there will be a spread of frequencies and therefore a spread of τ values as well, which leads to imperfect suppression. Another reason is poor selectivity. If you have many metabolites, this pulse will affect them considerably, not just the water (with the parameters above, it will affect anything not exactly @ 450 Hz).

Question 3
The OH peak doesn't give rise to a resonance due to exchange with the water. The only observable resonances come from CH_3 and CH. In the absence of splitting,



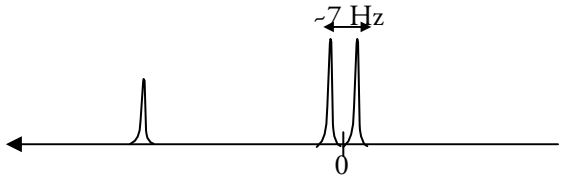
(the ppm axis is usually inverted, drawn from right to left, out of convention.)
In terms of Hz: the CH_3 is taken to be on resonance, meaning its frequency is 0. Furthermore,

$$1\text{ ppm} \approx \begin{cases} 64\text{Hz} & @1.5\text{T} \\ 128\text{Hz} & @3\text{T} \end{cases}$$

Since the difference in ppm is 3.775-1.467 = 2.308ppm, the distance between the peaks is

$$\Delta = 2.308\text{ppm} \approx \begin{cases} 147\text{Hz} & @1.5\text{T} \\ 295\text{Hz} & @3\text{T} \end{cases}$$

This means that the CH peak will appear at 147Hz @ 1.5T and at 295 Hz @ 3T.
Now let's introduce the splittings. The CH_3 peak gets split once by the H in the CH group:

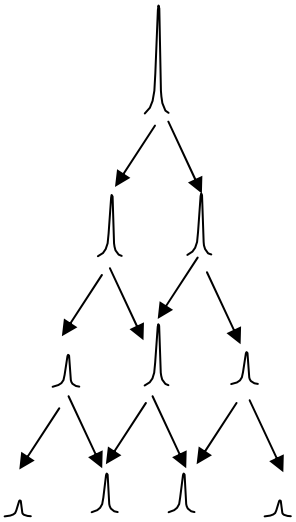


Next, the CH's proton will get split thrice by the CH_3 (since there are three protons in CH_3), resulting in a quartet (not drawn to scale):

First split:

Second split:

3rd split:



The distance between any two peaks here is 7 Hz (the size of the splitting).