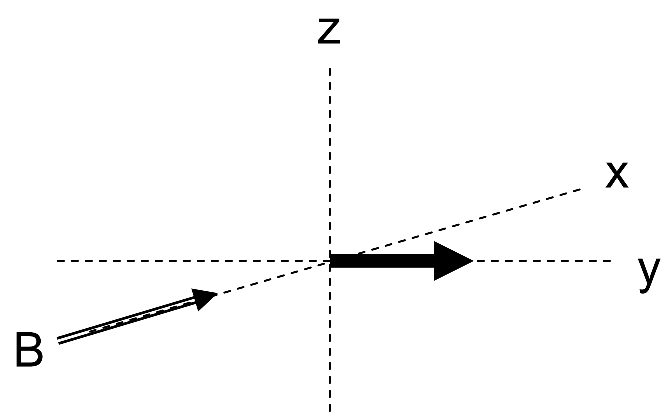
4.1

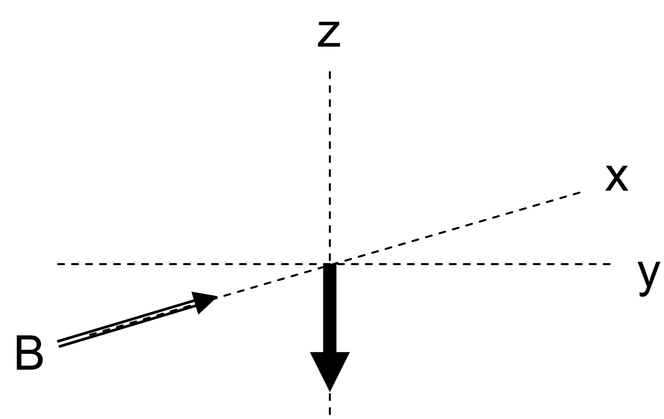
Using equation 4.20 from the text, $M_0 = \frac{\gamma^2 h^2 B_0 N_s}{16\pi^2 kT}$. For the parameters, $h = 6.63\times10^{-34} Js$, $B_0 = 1.5T$, $N_s = 6.7\times10^{22}$, $\gamma/2\pi = 42.58 MHz/T$ from table 4.1 of the text, $k = 1.38\times10^{-23} J/K$ and $T = 300K$ if we assume room temperature. Put in the numbers to the equation, we get $M_0 = \frac{\gamma^2 h^2 B_0 N_s}{16\pi^2 kT} = 4.837\times10^{-9} J/T$.

4.2

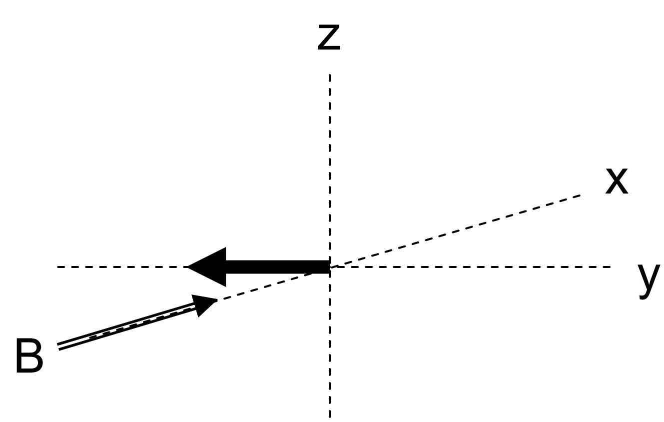
90°

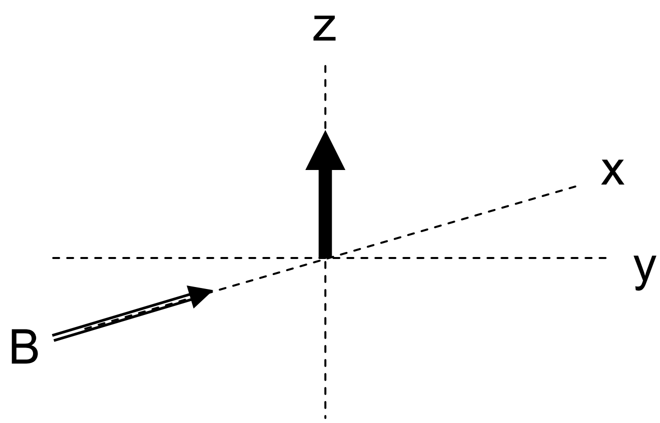


180°

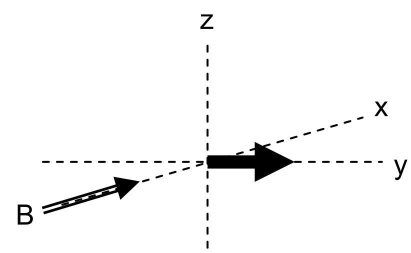
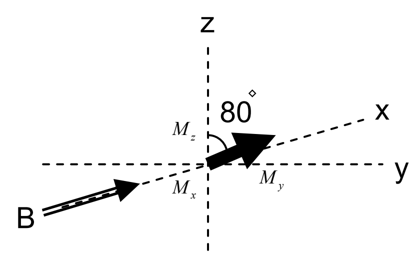
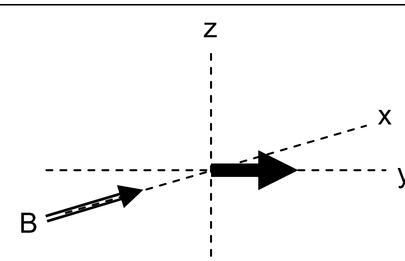


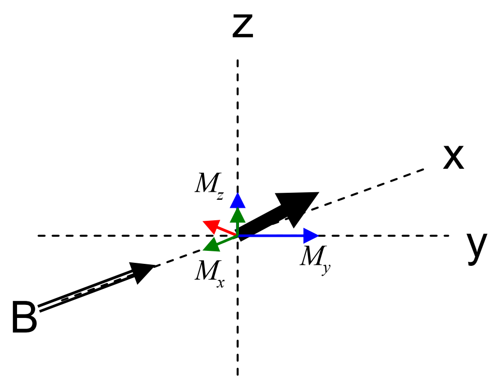
270°



360°	

4.3

Magnetiztion Components / B_1 pulses	M_x	M_y	M_z	Notes
(a) 90x	*0*	M_0	*0*	
(b) 80x	*0*	$M_0 \sin 80^\circ$	$M_0 \cos 80^\circ$	
(c) 90x90y	*0*	M_0	*0*	 90y magnetic pulse will not rotate the M_y since they have the parallel directions.

(d) 80x80y	$-M_0\cos80^\circ \sin80^\circ$	$M_0\sin80^\circ$	$M_0\cos^2 80^\circ$	 First step, 80x is the same as (b). Second step, M_y is the same as (c) (as blue arrows). M_x will rotate (as red arrows) and can be broken down to x and z direction components (Green arrows).

4.4

(a) F

A recovery from 90° pulse means in x-y direction, M is changing from M_0 to 0 and in z direction, M is changing from 0 back to M_0.

(b)T

Even in a perfectly homogeneous B_0 magnetic field, the magnetic moments of different protons precess at slightly different frequencies due to variations in their interactions with neighboring nuclei. As a result, the net magnetization decreases as a function of time.

(c)F

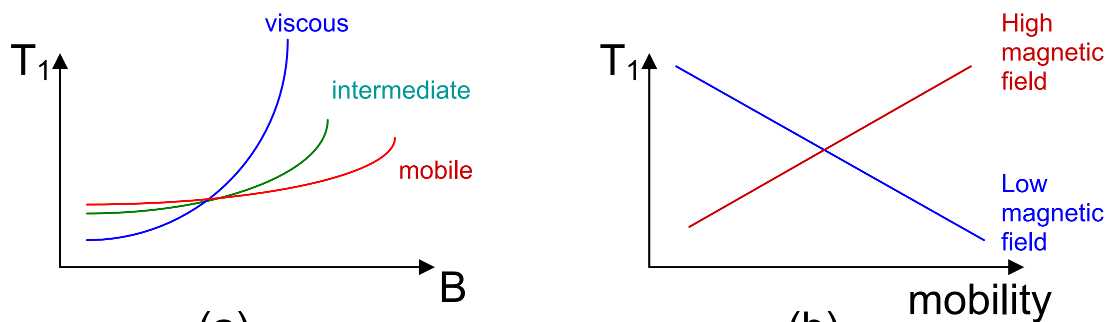
The physical basis for T_1 relaxation involves the protons losing their energy to the surrounding lattice.

(d)~~T~~ F

From equation $M_z(t) = M_0 \cos\alpha + (M_0 - M_0 \cos\alpha)(1 - e^{-t/T_1})$, we can know that the shorter T_1 is, the bigger M_z is for a fixed time, which means a shorter T_1 indicates a faster relaxation process.

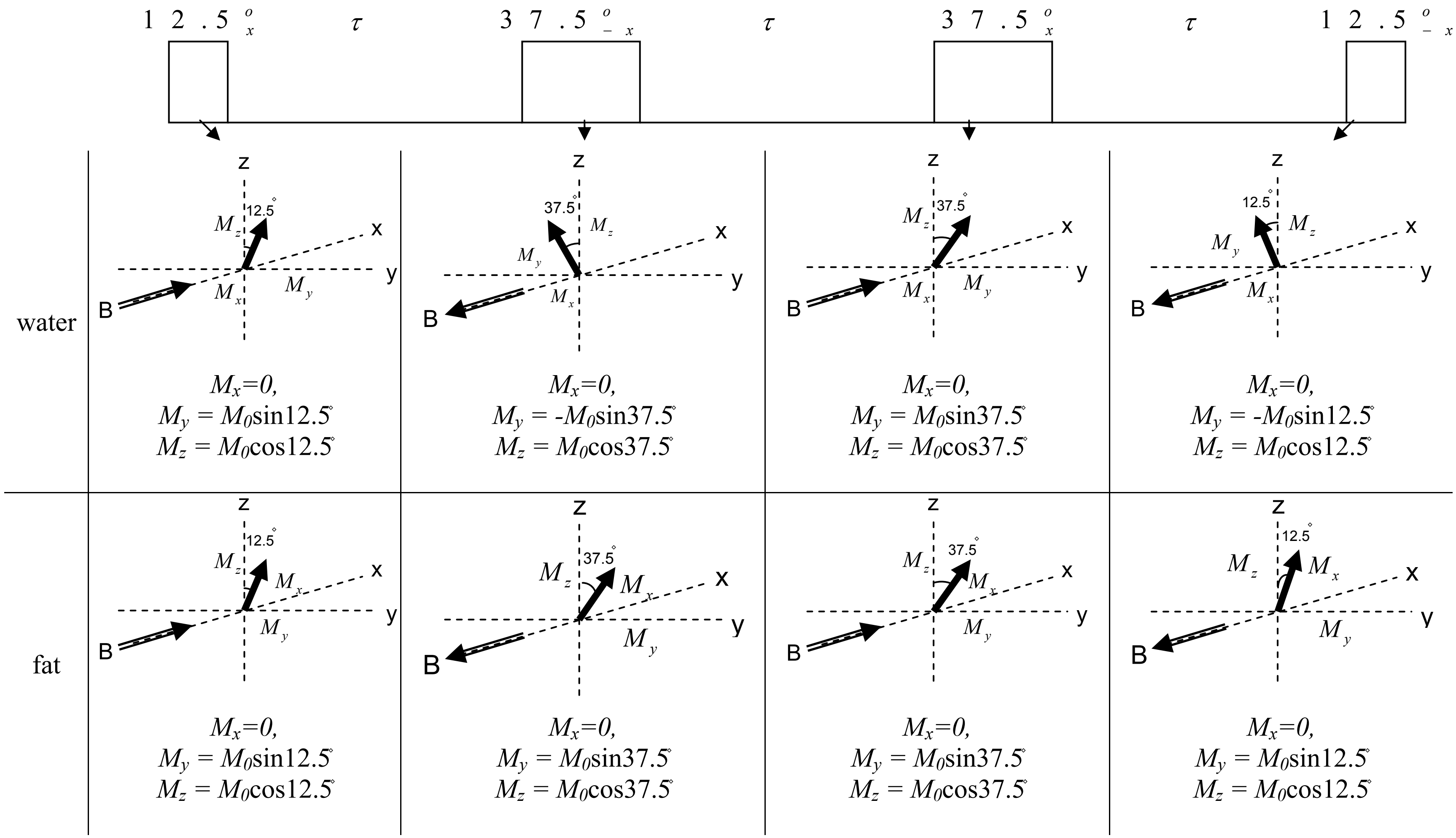
4.6

From part 4.5.2, we know that for lower magnetic field, the higher the viscosity of the tissue, the shorter T_1. On the other hand, for higher magnetic field, the higher the viscosity of the tissue, the longer T_1. This can be found from figure 4.30 of the text. And the relationships can also be plotted as below:



(a) (b)

4.5 Note: For fat proton, the precessional frequency is $\omega = \frac{\pi}{\tau}$ more than that of water proton. ω is much smaller than the frequency of the proton, so the angle differences for the two tissues can be neglected. And in the relaxation time τ , the fat proton will rotate π more in the x-y plane.



water	$M_x=0$, $M_y = M_0\sin 12.5°$ $M_z = M_0\cos 12.5°$	$M_x=0$, $M_y = -M_0\sin 37.5°$ $M_z = M_0\cos 37.5°$	$M_x=0$, $M_y = M_0\sin 37.5°$ $M_z = M_0\cos 37.5°$	$M_x=0$, $M_y = -M_0\sin 12.5°$ $M_z = M_0\cos 12.5°$
fat	$M_x=0$, $M_y = M_0\sin 12.5°$ $M_z = M_0\cos 12.5°$	$M_x=0$, $M_y = M_0\sin 37.5°$ $M_z = M_0\cos 37.5°$	$M_x=0$, $M_y = M_0\sin 37.5°$ $M_z = M_0\cos 37.5°$	$M_x=0$, $M_y = M_0\sin 12.5°$ $M_z = M_0\cos 12.5°$