→ Homework #1 (US) posted!
    (Due 4/25)

→ Homework #2 (ITI) up today / homework
    (Due 5/2)

→ Projects graded ... at home (Yay!)
(Nuclear) Magnetic Resonance (Imaging)

\[ E_{\text{N}} = 0.5 \text{ Gauss} \quad 1 \text{T} = 10^4 \text{ Gauss} \]

\[ \vec{B}_0 \]

charge "cir culated"

\[ \vec{F} \]

\[ \vec{z} = \vec{r} \times \vec{F} \]

\[ \vec{z} = \vec{\mu} \times \vec{B} \]

transverse terms cancel, result in \( \vec{r} \) along \( \vec{B}_0 \)

Precision occurs at a known, fixed freq : Larmor frequency \( \omega_0 = \gamma \vec{B}_0 \)

atomic specific \( \gamma \) gyromagnetic ratio

\[ \gamma \vec{h}_0 = 42.56 \text{ MHz/T} \]

RF freq.
Want to insert energy to transition some $\tilde{\mu}$ from $E_- \rightarrow E_+$. 

- Put energy in at Larmor freq.

Input energy can lead to $E_- \rightarrow E_+$ ("tip" the $\tilde{\mu}$) 

$\rightarrow \tilde{\mu}$ tips to a new angle

New into Newtonian mechanics

Controllable!!
spiral trajectory "down" tracing a sphere

tip angle is periodic as in duration of application of $\vec{B}_1$

coil

$H_x = \text{sinusoidal}$

induces sinusoidal current (EMF)
in the loop

$\text{[Faraday]}$
Relaxation

$\hat{\mathbf{H}}$ will recover to $\hat{\mathbf{H}}_0$ (along $\hat{\mathbf{B}}_0$)
as energy is lost ($E_+ \rightarrow E_-$)
...return to equilibrium!

Two categories:

1. Spin-Lattice Relaxation
2. Spin-Spin Relaxation

"Spin" = $\mu$ ... not quantum "spin"
\[ M_z(t) = M_{z0} - (M_{z0} - M_{z0} \cos \alpha) e^{-t/T_1} \]

For \( \alpha = 90^\circ \) \( \rightarrow M_{z0} (1 - e^{-t/T_1}) \)

Strong for if molecule in which proton is located
It was constructed from spin cone ... lots of it

\[ \vec{B}_0 \]

... experience constant \[ \vec{B}_0 \]

Plus surrounding B-field

due to neighboring spin ... 

... true-vari magnetic field

Each

\[ \vec{B}_0 \]
slightly different

\[ \vec{B}_{eff} \] \[ \rightarrow \] New \[ \phi \] angle

\[ \rightarrow \] New \[ \vec{B}_0 \]

\[ \phi \] now be positionally variable WITHIN compound

... lose that please coherence quite \[ \rightarrow \] rapidly

As phase is lost \[ \vec{M}_y \] \[ \rightarrow \] 0.
Therefore... transverse $\hat{F} \to 0$ as please of the core $\Rightarrow$ thermal equilibrium.

$M(x,t) \xrightarrow{\text{decay governed by } T_2} M(x,0) \text{ e}^{-t/T_2}$

$\Rightarrow T_2 \text{ decay must be faster than } T_1 \text{ relaxation}$

$[T_1 \geq T_2]$

Each tissue has unique $(T_1, T_2)$ $\Rightarrow$ differentiate tissues by weighting acc. by $T_1 \cdot T_2$. 
In our basic experiment, we find... signed decays with $T_2$. 

\[ \text{Val} \]

\[ M_0(t) = (M_0 \sin \alpha e^{-t/\tau}) \cos \omega t \]

\[ \text{decay envelope} \]

\[ \text{carrier frequency} \]

Bose<br>Purdue 1933

Penfield, Torrey & Pound (1946)