

PHY138Y
Nuclear and Radiation

Professor Tony Key
MP401
key@physics.utoronto.ca



The Test was

- A. Too easy
- B. OK
- C. Too hard

The Test was

- A. Too short
- B. OK
- C. Too long

The Test was

- A. Excessively Fair
- B. Extremely Fair
- C. Very Fair
- D. Fair
- E. I just loved it!

Announcements

Extra Help: I'll be around mostly till the exam, but best to email me for an appointment.

Readings

Today

SNVI

Finish NMR & MRI
(NOT ON THE EXAM!)

The Three Steps of MRI

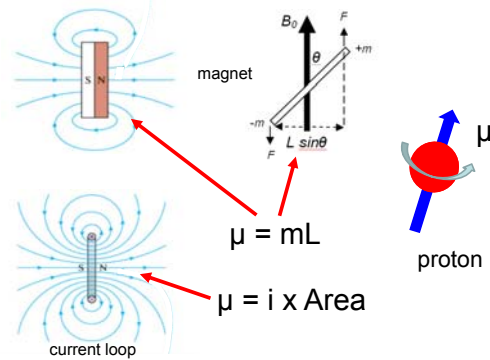
1. Generation of the signal
2. Localization of the signal
3. Identification of the signal

GENERATION OF THE SIGNAL

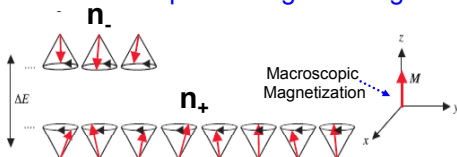
Three steps:

- A. Apply strong magnetic field
- B. Apply resonant rf field
- C. Measure strength of emitted Larmor frequency

These all have a Magnetic Moment



NMR – protons aligning and precessing in a magnetic field



Spin up protons/spin down protons $n_+/n_- = \exp(-\Delta E/kT)$

Macroscopic magnetic field from protons
 $= (n_+ - n_-) \mu$

NMR – protons aligning and precessing in a magnetic field

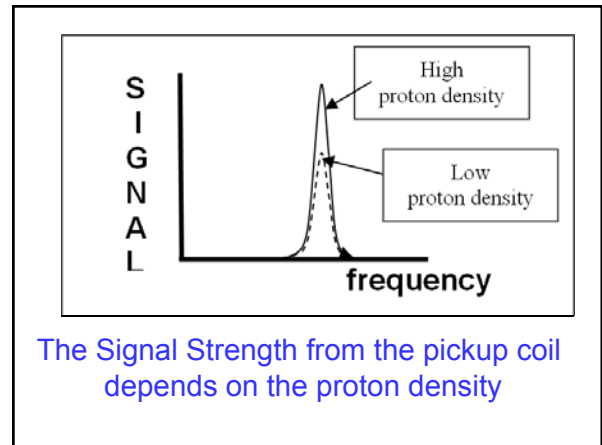
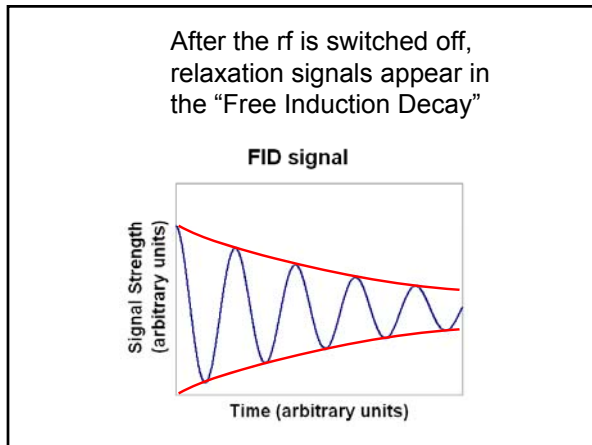
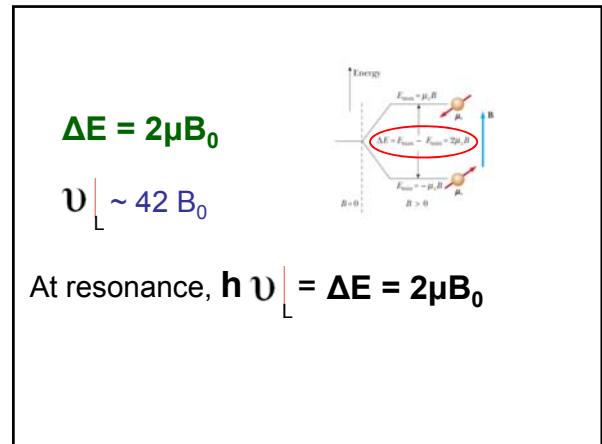
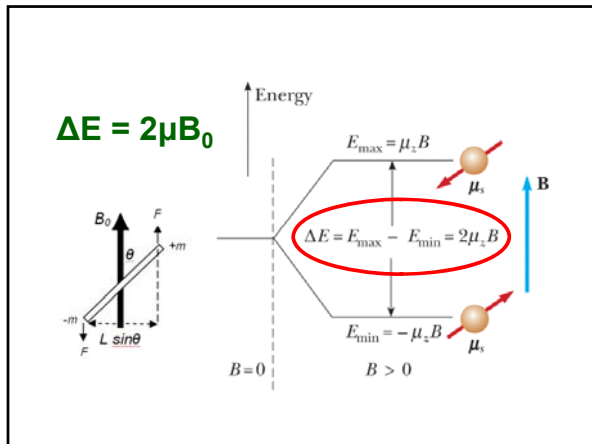
Frequency of Precession = Larmor Precession

$$= \omega_L = 2\pi \nu_L = \gamma B_0$$

γ is gyro-magnetic ratio
 = magnetic moment/spin
 $= \mu / (\frac{1}{2} \hbar)$ (with $\hbar = h/2\pi$)

$$\nu_L \sim 42 B_0$$

in MHz in Tesla



LOCALIZATION OF THE SIGNAL

Paul Lauterbur

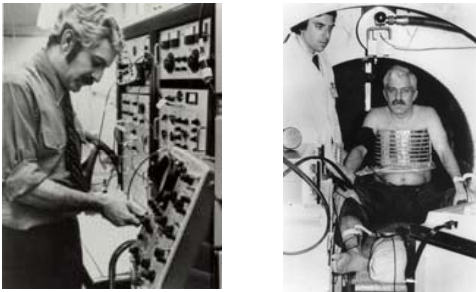
University of Illinois

Nobel Prize 2003

**Peter
Mansfield**
University
of
Nottingham
Nobel Prize
2003



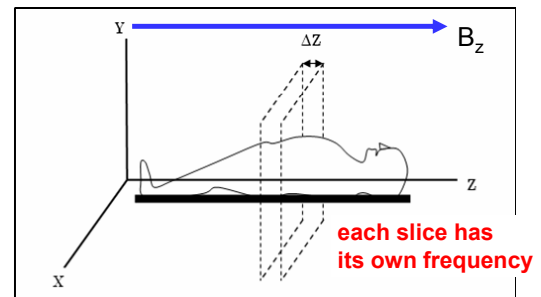
Briton, American share Nobel



Raymond Damadian

Lauterbur's BrainWave

$$B_z = B_0 + zG_z$$



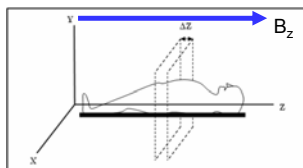
Lauterbur's BrainWave

$$\omega_L = \gamma B_z = \gamma(B_0 + zG_z)$$

measure (pointing to ω_L)
known (pointing to B_0)
known (pointing to G_z)
calculate (pointing to zG_z)

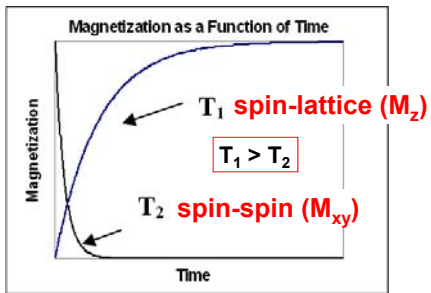
$$\Delta\omega = \gamma G_z \Delta z$$

analyse
frequency
spectrum



**IDENTIFICATION
OF
THE SIGNAL**

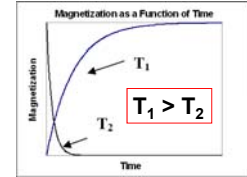
When B_1 is switched off, spins relax...



When B_1 is switched off, spins relax...

spin-lattice (M_z)
 $M_z = |M|(1 - \exp(-t/T_1))$

spin-spin (M_{xy})
 $M_{xy} = |M|\exp(-t/T_2)$



Relaxation Times at 1.5 T
 (healthy volunteer)
 error ~ 10%

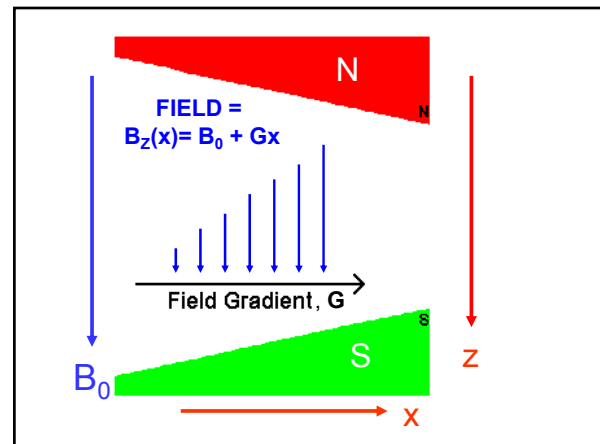
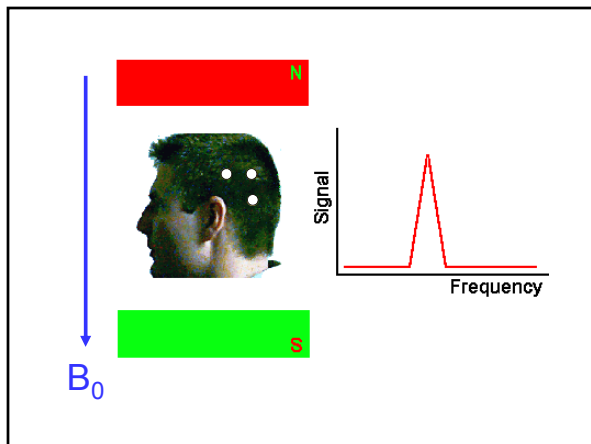
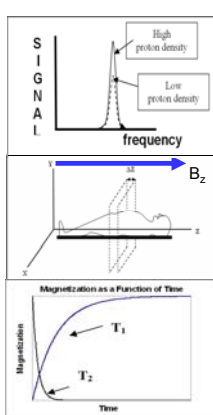
Tissue	T1 (ms)	T2 (ms)
Grey Matter	1079	100
White Matter	684	79
Spinal Fluid	3959	914

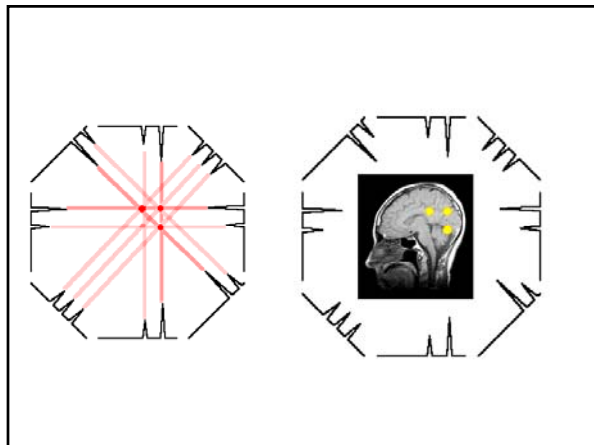
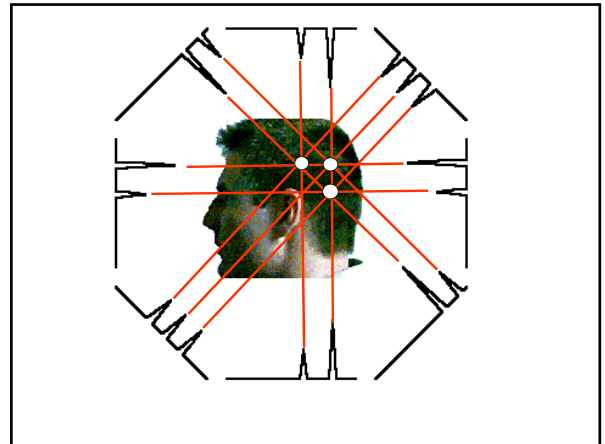
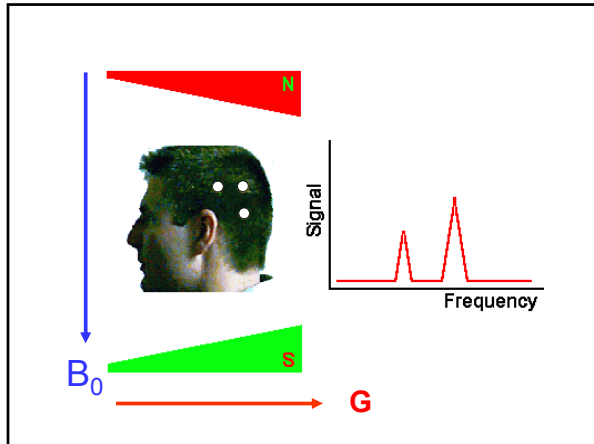
MRI summary

The strength of the signal gives the density of protons,

the measurement of frequency gives the position

measurement of T1 and T2 provide contrast and discrimination.





The sample shown has three capsules of water, Shown as black dots. An MRI signal is obtained. Which of the graphs best approximates the frequency spectrum of the Larmor frequency measurements?

B_0 N S G

A **C** D E

Five graphs labeled A through E, each showing a different frequency spectrum. Graph C is circled in red, indicating it is the correct answer. The graphs show varying numbers and heights of peaks.

