Aalto University
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Brief Recap of Chapter 1 of Brown et al. (2014)

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Contents of Chapter 1 ”Magnetic Resonance Imaging: A Preview”

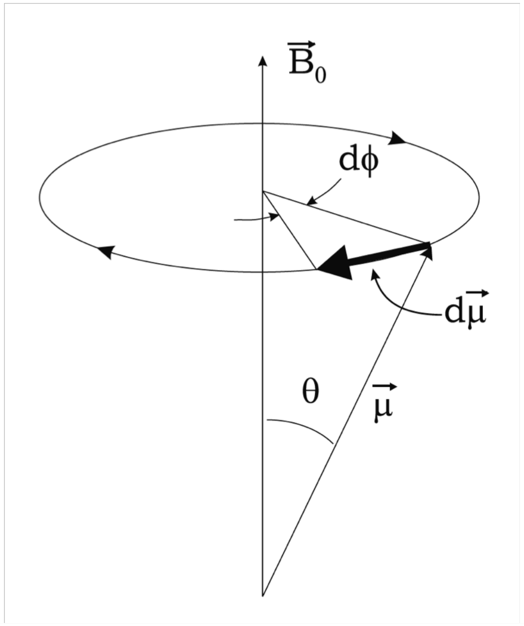
Basics of MRI: A Preview (video)
https://youtu.be/hgPcKNzjmBQ

Introduction

- **Magnetic Resonance Imaging: The Name**
  - Nuclear magnetic resonance (NMR) imaging
- **The Origin of Magnetic Resonance Imaging**
  - Stern and Gerlach from the early 1920's
  - Rabi and coworkers in the 1930's (spin-magnetic field)
  - Bloch's and Purcell's group's work in 1940's
  - 1973 seminal papers by Lauterbur and Mansfield

Fundamental Interaction of a Proton Spin with the Magnetic Field

- Interaction of a nuclear spin with an external magnetic field, B_0
- Spin precession
- In 1T field the spins precess at 42.6MHz
- Larmor frequency
- Larmor equation



$$\omega_0 = \gamma B_0$$

Brief Overview of MRI Concepts

- **Equilibrium Alignment of Spin**

$$\text{spin excess} \simeq N \frac{\hbar\omega_0}{2kT}$$

$$M_0 \quad = \quad \frac{\rho_0 \gamma^2 \hbar^2}{4kT} B_0$$

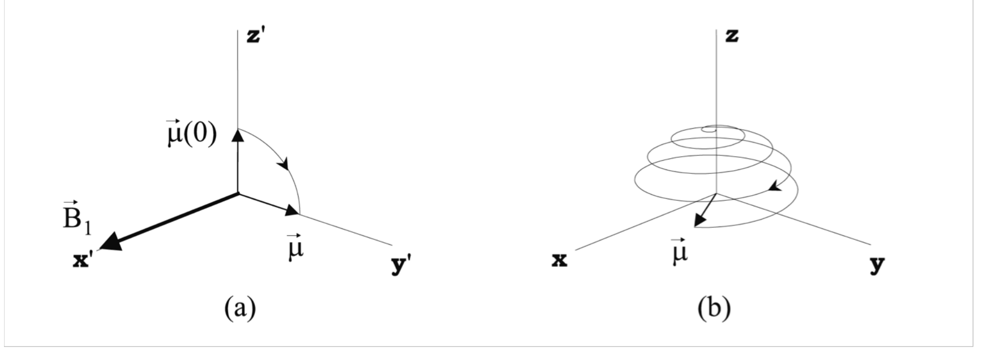
- **Problem:**

Problem 1.1

Using $\hbar = 1.05 \times 10^{-34}$ joules, $k = 1.38 \times 10^{-23}$ joule/K and $T = 280\,\mathrm{K}$, find the spin excess as a fraction of N for protions at 0.35 tesla.

Brief Overview of MRI Concepts

- **Detecting the Magnetization of the System**
  - Magnetization is first flipped with RF pulse
  - The magnetization is measured with receive coil



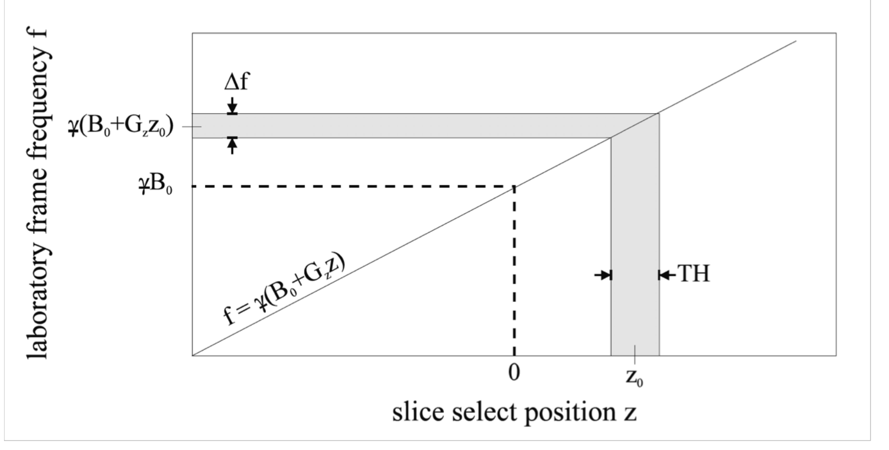
$$emf = -\frac{d}{dt}\int d^3r \vec{M}(\vec{r},t)\cdot\vec{\mathcal{B}}^{receive}(\vec{r})$$

$$\text{signal} \propto \frac{\gamma^3 B_0^2 \rho_0}{T}$$

Brief Overview of MRI Concepts

- **Magnetic Resonance Spectroscopy**
- **Magnetic Resonance Imaging**

$$\omega(x) = \gamma B(x)$$



- **Relaxation Times**

$$M_z(t) = M_0(1 - e^{-t/T_1})$$

$$M_\perp(T_E) = M_0(1 - e^{-T_R/T_1})e^{-T_E/T_2}$$

- **Resolution and Contrast**
- **Magnetic Field Strength**
- **Key Developments in Magnetic Resonance**

Brief Overview of MRI Concepts

Category	Subcategory	Frequency (MHz)	Field strength (T)	Wavelength (m)
radio waves	LF (long wave)	0.03–0.3	7×10^{-4}–7×10^{-3}	10^4–10^3
	MF (medium wave)	0.3–3	7×10^{-3}–0.07	10^3–10^2
	AM radio (MF)	0.52–1.71	0.012–0.04	577–175
	HF (short wave)	3–30	0.07–0.7	10^2–10
	VHF	30–300	0.7–7	10–1
	FM radio (VHF)	87.5–108	2.05–2.54	3.43–2.78
	UHF	300–3×10^3	7–70	1–0.1
	SHF	3×10^3–3×10^4	70–700	0.1–0.01
microwaves		10^4–3×10^5	235–7×10^3	0.03–10^{-3}

Problem 2

$$\omega_0 = \gamma B_0$$

hydrogen proton has a
γ value of roughly $2.68*10^8$ rad/s/tesla

c = f λ

Problem 1.2

Find the frequency and free-space wavelength associated with the rf field required for proton magnetic resonance at each of the different B_0 values of a) 0.08 T, b) 0.4 T, c) 1.6 T, and d) 8 T.