Dito galing lahat Quiz & Exam

MRI PHYSICS

NUCLEAR PHYSICAL PRINCIPLE

MRI
→ taking an image / signal from an atom that is within the body

Human body compose of hydrogen atom
↳ main source of signal

- we target each atom and collect signals that is coming from out of atom & converting these signal into an image
- same w/ MRI except theres no ionization of the atom

How we acquire image

- lahat ng hydrogen atom, has characteristic called nuclear spin (they are call nuclear coz they have nucleus.—the center of atom that makes it neutral)

CHRISTOPHER TEMPLO, RRT

* each pt / atom in the body has its own orbital & characteristics (like solar system)

as they spin they process energy & they release energy

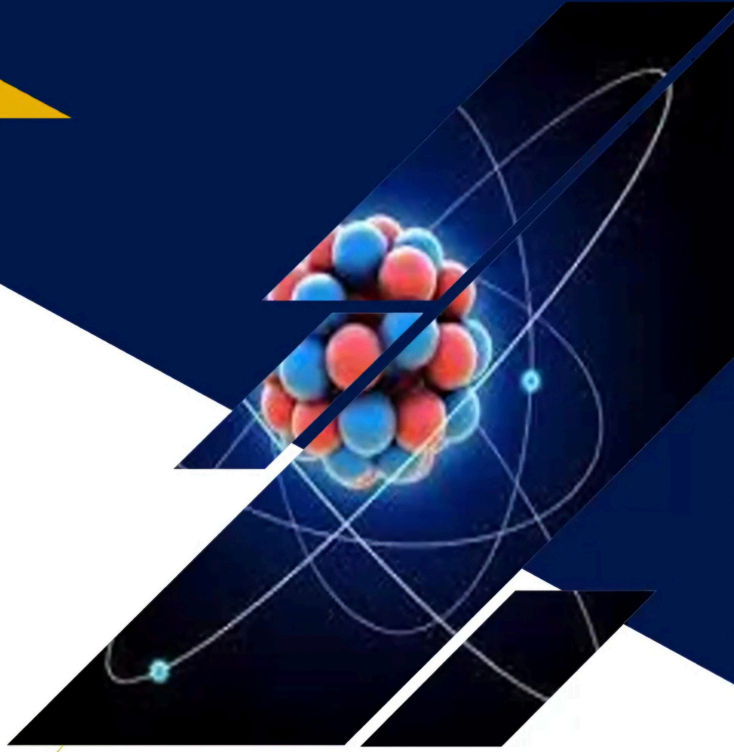
NUCLEAR SPIN

↳ main charac of atom

What is Nuclear Spin?

all atom in our body are characterized with ?

The nuclear spin, is a quantum number assigned to each nuclear state and represents the total angular momentum of an atomic nucleus corresponding to the sum of the angular momentum of each of its nucleons including the orbital and 'intrinsic' spin angular momentum.



NUCLEAR SPIN

p+ spin
e- spin - revolve around p+

How does Nuclear Spin interacts?

Nuclear spins interact with surrounding electrical environment and electron spins interact with surrounding nuclear spin environment. These interactions lead to a small shift and/or splitting of energy levels and are called hyperfine interactions.

NUCLEAR SPIN

Who creates Nuclear Spins?

main proton

Hydrogen nuclei (protons) have magnetic properties, called **nuclear spin.** They behave like tiny rotating magnets, represented by vectors.

↳ They Rotate & release energy, they also interact w/ each other or to their neighboring p+ kaya the behave like magnet

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HYDROGEN NUCLEI

→ combine all atom that spin w/ the same frequency & energy & same direction

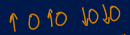
The sum of all the tiny magnetic fields of each spin is called **net magnetization or macroscopic magnetization.** Normally, the **direction** of these vectors is **randomly distributed.** Thus, the sum of all the spins gives a **null net magnetization.**

↳ kabuuan w/ diff. energy / frequency and direction in the human body

Ex.
Proton before aligning in diff direction

magnetic field
low energy = will align with the main MF
high energy = will align anti-parallel to MF

B0



- during alignment they still spin

Within a **large external magnetic field** (called **B0**), nuclear spins align with the external field. Some of the spins align **with** the field (**parallel**) and some align **against** the field (**anti-parallel**).

parallel
→ if the energy is equivalent or lower than the magnetic field nuclear spin align

anti-parallel
→ if the energy is higher than the MF or external MF

NUCLEAR SPIN

When is nuclear spin produced?

present in w/ the water

In clinical MRI, Hydrogen is the most frequently imaged nucleus due to its great abundance in biological tissues.

Other nuclei such as 13C(carbon), 19F(fluorine), 31P(phosphorus), 23Na(sodium) have a net nuclear spin and can be imaged in MRI. However, they are much less abundant than hydrogen in biological tissues and require a dedicated RF chain, tuned to their resonance frequency.

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Gyromagnetic Ratio

↗ all atom has this

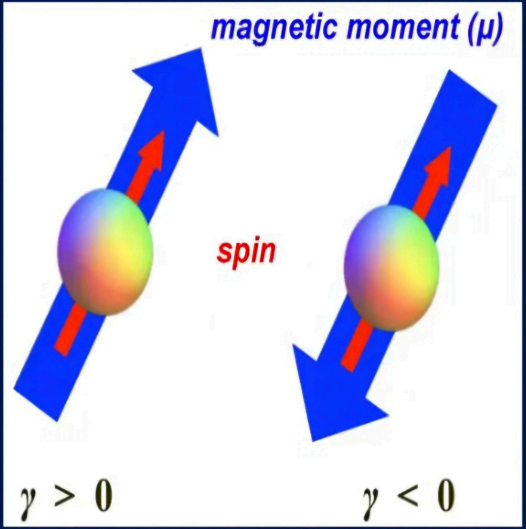
→ sa pag spin nila theres a momentum / they have their own angular momentum

2 types of gyromagnetic
1. Greater than the external MF
2. Lower than the " "

Tale of the Gyroscope

In physics, the gyromagnetic ratio of a particle or system is the ratio of its magnetic moment to its angular momentum, and it is often denoted by the symbol γ, gamma. Its SI unit is the radian per second per tesla or, equivalently, the coulomb per kilogram.

The value of the gyromagnetic ratio (γ) varies by atomic species. The units of γ are typically given in the form of [frequency] ÷ [magnetic field strength], such as (radians/sec)/gauss or MHz/tesla.



Gyromagnetic Ratio

y=MHz/Tesla

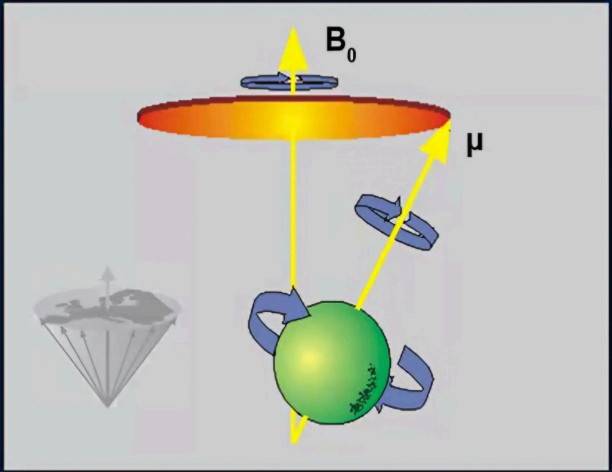
Nucleus or Particle	Gyromagnetic Ratio (γ) in MHz/Tesla
^{1}H	42.58
^{3}He	-32.43
^{13}C	10.71
^{19}F	40.05
^{23}Na	11.26
^{31}P	17.24
electron	-27,204

Larmour Frequency

Precessional Frequency

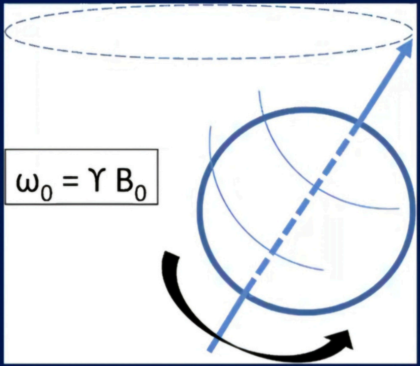
The Larmour or precessional frequency in MRI refers to the rate of precession of the magnetic moment of the proton around the external magnetic field. The frequency of precession is related to the strength of the magnetic field, B0.

The torque exerted then produces a change in angular momentum which is perpendicular to that angular momentum, causing the magnetic moment to precess around the direction of the magnetic field rather than settle down in the direction of the magnetic field. This is called Larmor precession.

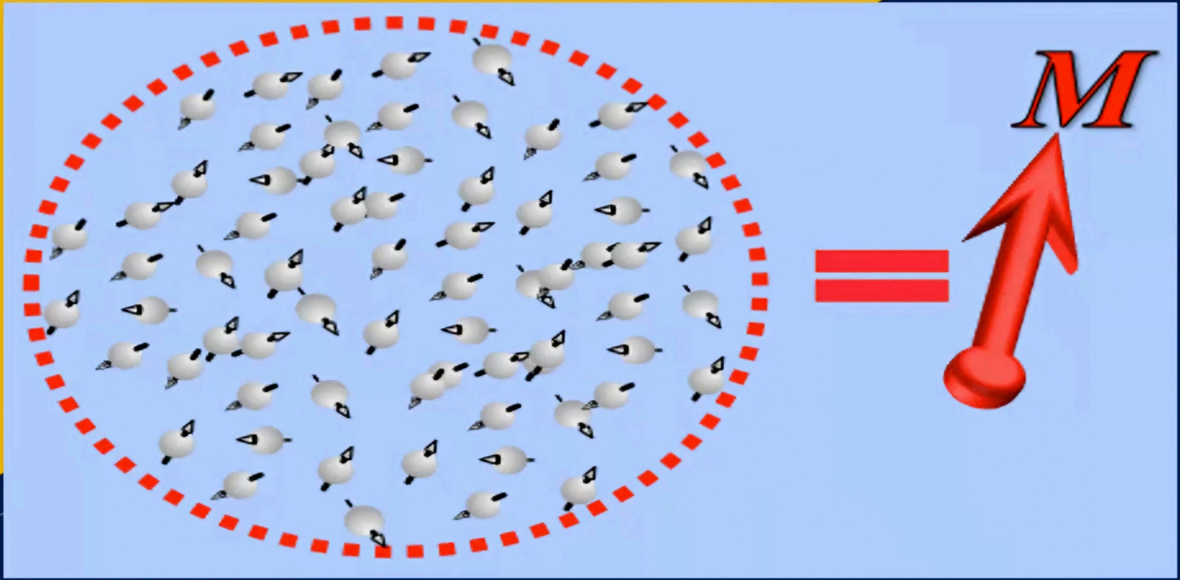


Larmour Equation

The precessional frequency of nuclei of a substance placed in a static magnetic field (B0) is calculated from the Larmor Equation $\omega = \gamma B$, where ω is the Larmor frequency (in MHz), γ is the gyromagnetic ratio (in MHz/T) and B is the strength of the static magnetic field (in T).



NET MAGNETIZATION



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NET MAGNETIZATION VECTOR

The net magnetization vector in MRI is the summation of all the magnetic moments of the individual hydrogen nuclei. In the absence of an external magnetic field, the individual magnetic moments are randomly oriented and since they are in opposition, the net magnetization vector is considered to be zero.

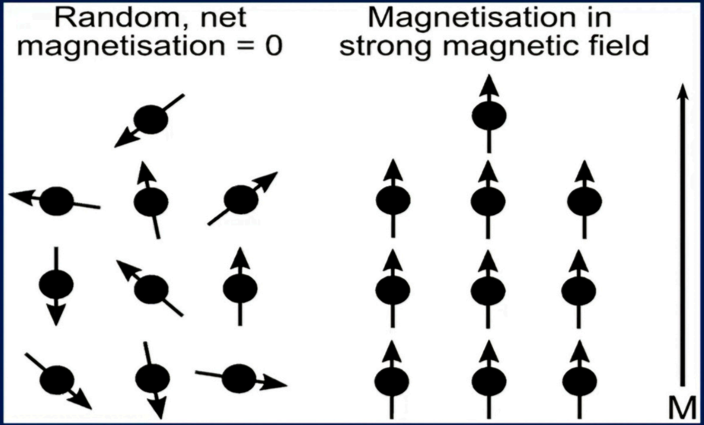
If hydrogen nuclei are placed within a strong external magnetic field, they become aligned within the field in one of two directions parallel to the direction of the field.

NET MAGNETIZATION VECTOR

In MRI, the main magnetic field is termed B0.

-aligned in the direction of B0 (parallel)

-aligned in the opposite direction of B0 (antiparallel)



NET MAGNETIZATION VECTOR

A parallel and antiparallel hydrogen nuclei have equal but opposite magnetic moments and cancel each other out. However, there are always slightly more hydrogen nuclei parallel to B0 and this slight difference is termed the NMV (net magnetization vector) and given the symbol M.

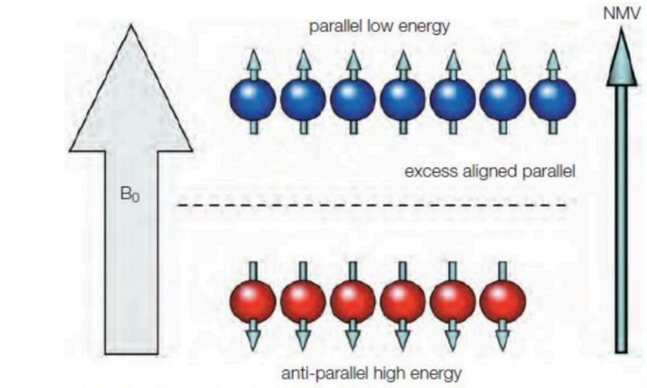
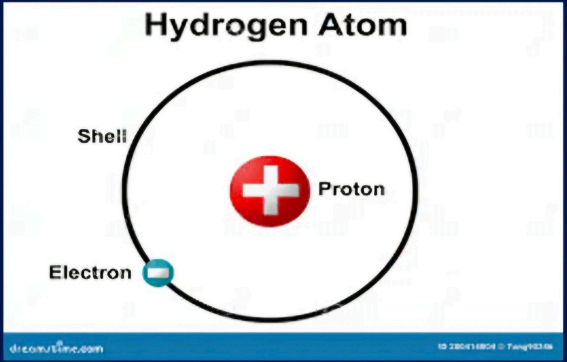


Figure 3.3 The net magnetization vector (NMV).

NET MAGNETIZATION VECTOR

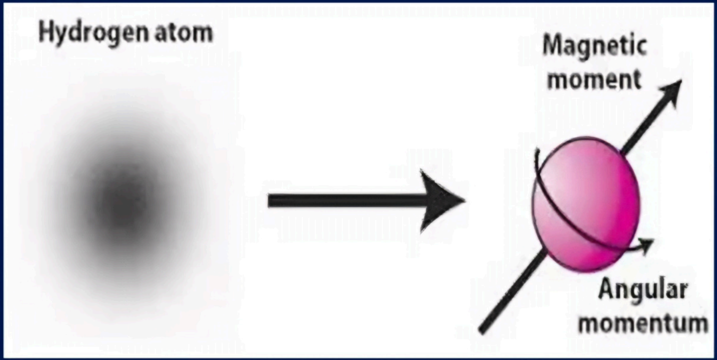
The energy difference between spin up and spin down states of hydrogen are important in understanding net magnetization vector of tissue for magnetic resonance imaging.

Each hydrogen atom is formed by one proton and one orbiting electron. Because the atomic number is 1, it has a spin quantum number 1/2. Hence, the hydrogen proton can exist in two spin states: 'up' state and 'down' state.

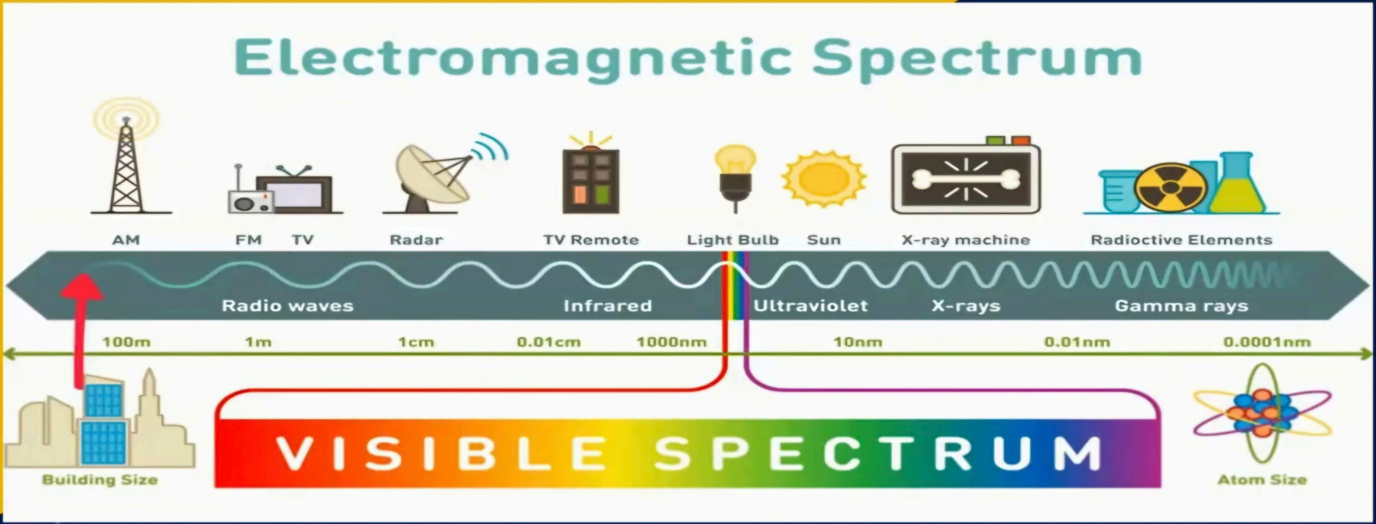


NET MAGNETIZATION VECTOR

The hydrogen proton has a positive charge and can also generate magnetic dipole moments. When a magnetic field is applied to a proton dipole, the dipole will either align 'parallel' or 'anti-parallel' relative to the direction of the magnetic field depending on its spin state.



RADIOFREQUENCY



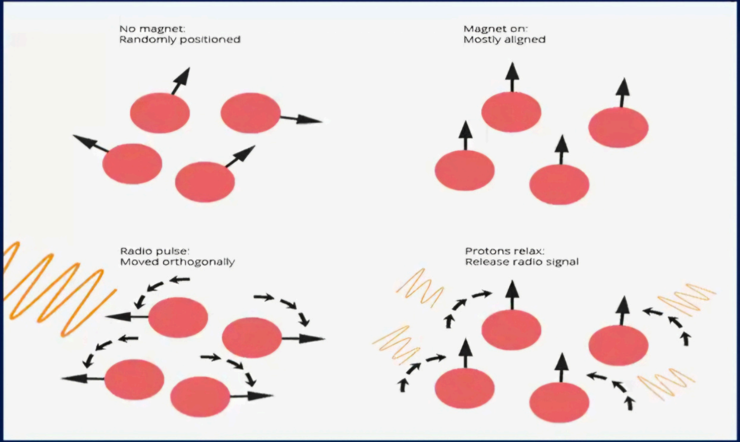
RADIOFREQUENCY FIELD

Radiofrequency magnetic fields are critical to nuclear excitation and signal reception in Magnetic Resonance Imaging (MRI). The interactions between these fields and human tissues in anatomical geometries results in a variety of effects regarding image integrity and safety of the human subject.

Radiofrequency (RF) fields, or radio waves, come from the towers and antennas that produce and transmit radio and telecommunication signals. The RF fields make up the electromagnetic wave, or radiation, which is the radio signal. This is non-ionizing radiation.

RADIOFREQUENCY FIELD

The strong magnetic field created by the MRI scanner causes the atoms in your body to align in the same direction. Radio waves are then sent from the MRI machine and move these atoms out of the original position. As the radio waves are turned off, the atoms return to their original position and send back radio signals.



RADIOFREQUENCY FIELD

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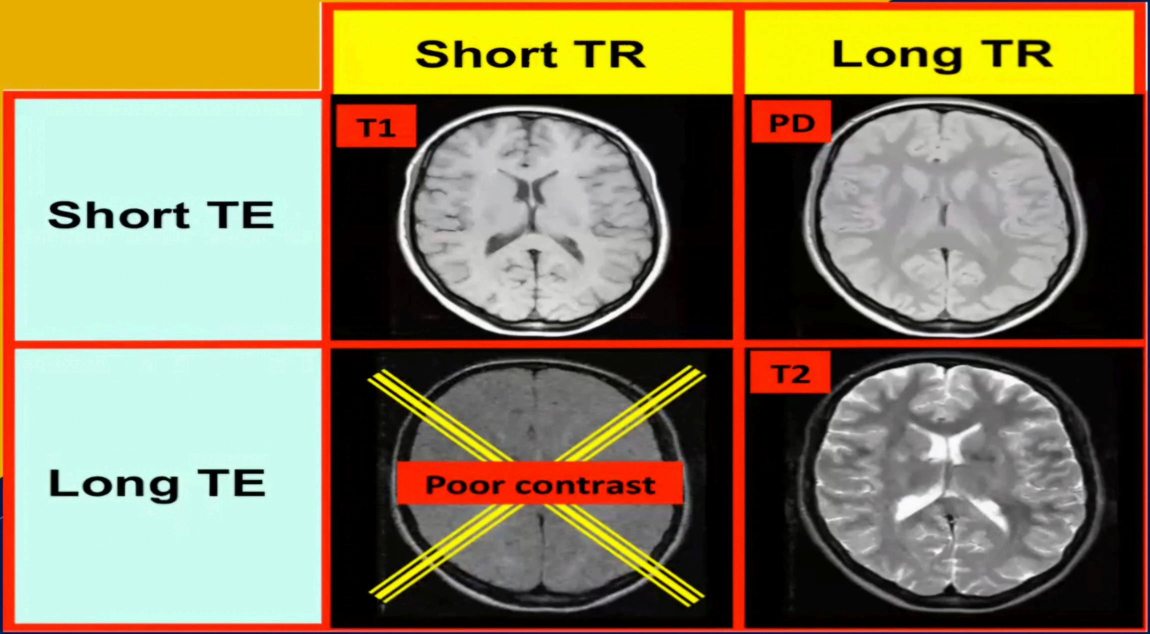
Modern devices often generate electromagnetic fields of radio frequency (RF) ranging from 100 kHz to 300 GHz. Key sources of RF fields include mobile phones, cordless phones, local wireless networks and radio transmission towers. They are also used by medical scanners, radar systems and microwave ovens.

RF is generated by a transmitter and detected by a receiver. The transmitter antenna turns electrical signals into radio waves, giving it the ability to travel long distances. The receiver antenna catches the radio waves and turns them back into electrical signals, which feed into the computer system.

SPIN DENSITY



SPIN DENSITY

The spin density is the concentration of signal bearing spins. The instrumental variables are the: Repetition Time/TR. Echo Time/TE. Inversion Time/TI. These variables are often called "scan parameters".

They can be similar to the Technical factors used in X-rays like the kVp, mA, Time (s).

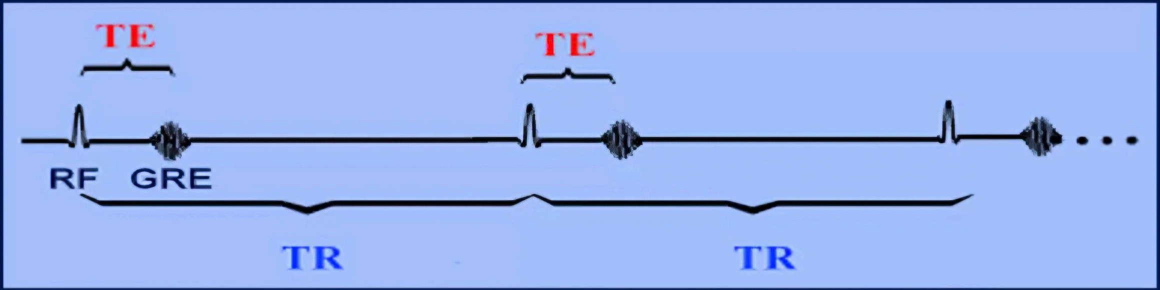
Tissue	Relative Number of Mobile Protons % (Spin Density)
White matter	100
Fat	98
Gray matter	94
Liver	91
Bone	~5
Lung	~3

SPIN DENSITY

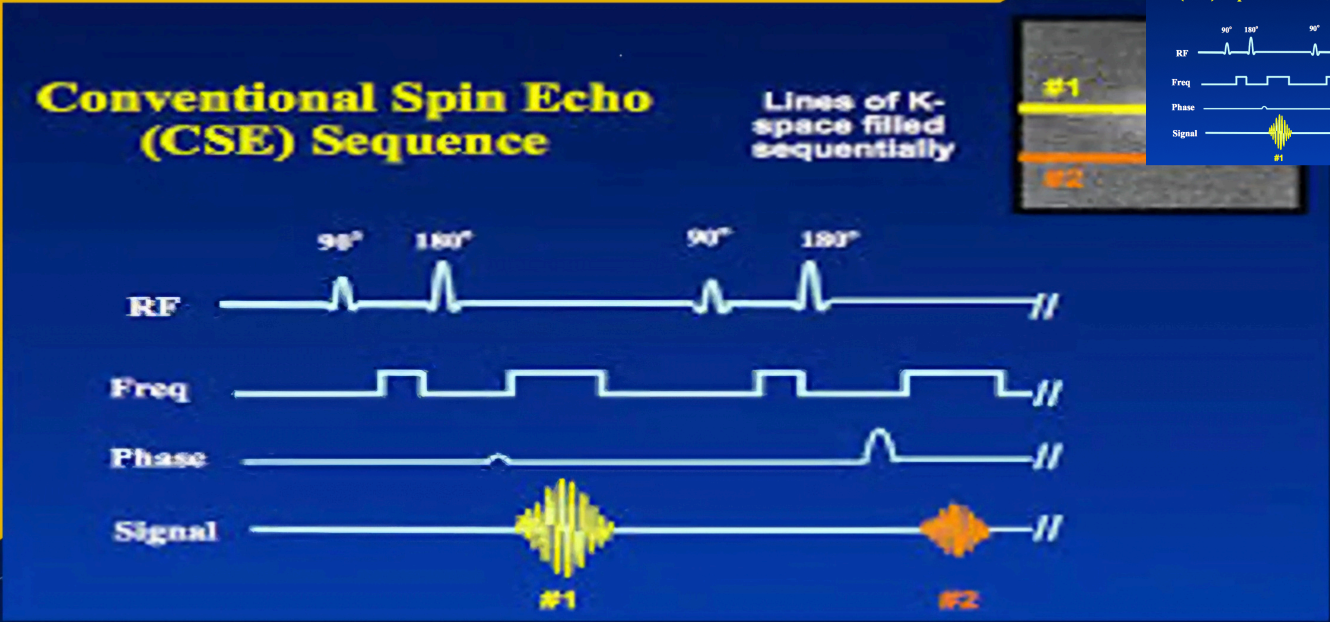
Repetition Time (TR) is the amount of time between successive pulse sequences applied to the same slice.

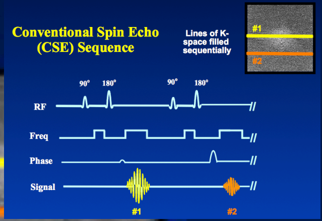
Time to Echo (TE) is the time between the delivery of the RF pulse and the receipt of the echo signal.

Inversion Time (TI) is the time elapsed between the preparatory 180° pulse and the 90° excitation (slice selection) RF pulse is termed time to inversion (TI).



PULSE SEQUENCE





PULSE SEQUENCE

An MRI pulse sequence is a programmed set of changing magnetic gradients. Each sequence will have a number of parameters, and multiple sequences grouped together into an MRI protocol.

A pulse sequence is generally defined by multiple parameters. Different combinations of these parameters affect tissue contrast and spatial resolution.

MRI sequences can be grouped in a number of ways. Probably most accurately they are grouped according to the type of sequence (e.g. spin echo, or inversion recovery etc..) however for non radiologists another way of grouping sequences is by general image weighting (e.g. T1 or T2) and additional features (e.g. fat suppressed or gadolinium enhanced).

TYPES OF PULSE SEQUENCE

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Spin Echo- In magnetic resonance, a **spin echo** or **Hahn echo** is the refocusing of spin magnetization by a pulse of resonant electromagnetic radiation.

The spin echo sequence is made up of a series of events : 90° pulse – 180° rephasing pulse at TE/2 – signal reading at TE. This series is repeated at each time interval TR (Repetition time). With each repetition, a k-space line is filled, thanks to a different phase encoding.

TYPES OF PULSE SEQUENCE

Fast/ Turbo Spin Echo-FSE/TSE is more efficient because multiple echoes are recorded after each 90-degree excitation pulse (multiple echoes per TR). This is achieved by transmitting a series of 180-degree inversion pulses at set intervals and measuring the corresponding echo according to a slightly different phase encoding gradient.

TYPES OF PULSE SEQUENCE

Gradient Echo- Gradient echo sequences (GRE) are an alternative technique to spin-echo sequences, differing from it in two principal points: utilization of gradient fields to generate transverse magnetization. flip angles of less than 90°.

Compared to the spin-echo and inversion recovery sequence, gradient echo sequences are more versatile. Not only is the basic sequence varied by adding dephasing or rephasing gradients at the end of the sequence, but there is a significant extra variable to specify in addition to the usual TR and TE. This variable is the flip or tip angle of the spins.

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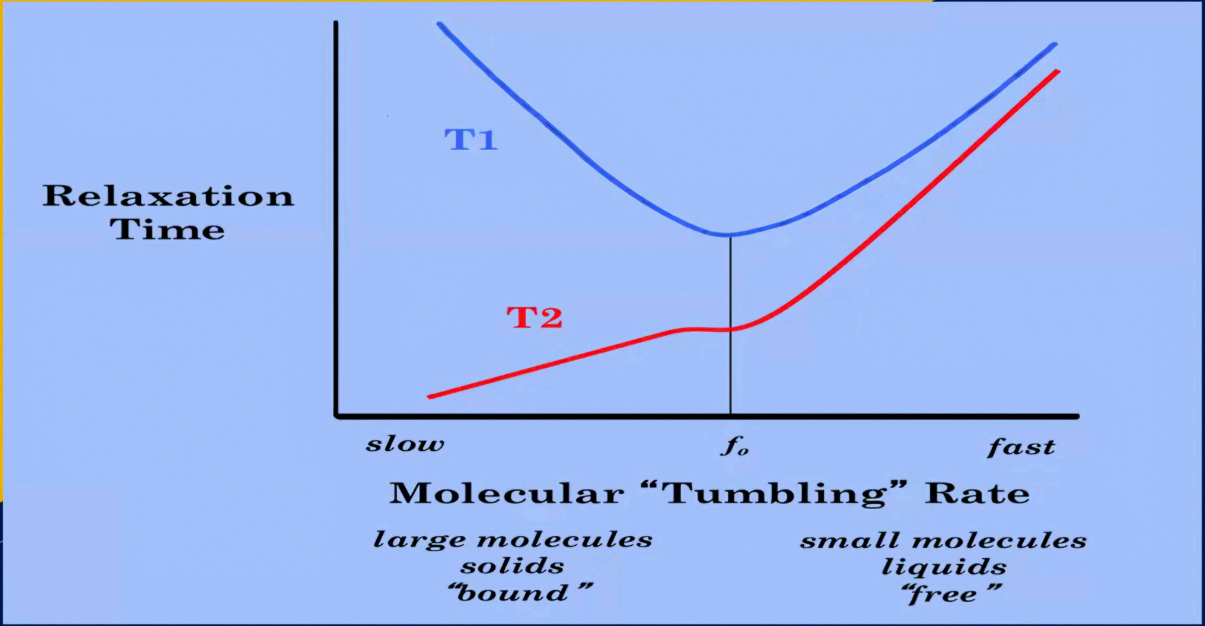
TYPES OF PULSE SEQUENCE

Inversion Recovery- Inversion-recovery (IR) is a magnetization preparation technique followed by an imaging sequence of the spin echo type in its « standard » version. The sequence starts with a 180° RF inversion wave which flips longitudinal magnetization Mz in the opposite direction (negative).

Inversion recovery pulse sequences are a type of MRI sequence used to selectively null the signal for certain tissues (e.g. fat or fluid).

Inversion recovery can also generate heavily T1-weighted images and was originally developed for this purpose.

RELAXATION TIME



RELAXATION TIME

Return to equilibrium of net magnetization is called Relaxation. During relaxation, electromagnetic energy is retransmitted, this RF emission is called the NMR signal. Relaxation combines 2 different mechanisms.

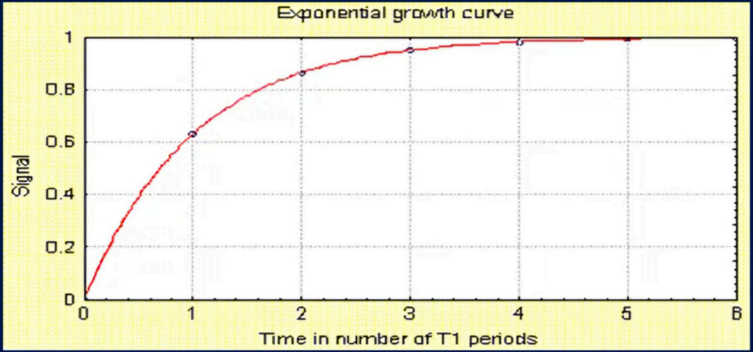
Tissue can be characterized by two different relaxation times – T1 and T2.

The relaxation time is a measure of the rotational freedom of magnetic nanoparticles, which provides information on several material characteristics, such as the viscosity, chemical bonding, and stiffness of the matrix to which the nanoparticles are bonded.

T1 RELAXATION TIME

The T1 relaxation time, also known as the spin-lattice relaxation time or longitudinal relaxation time, is a measure of how quickly the net magnetization vector (NMV) recovers to its ground state in the direction of B0.

T1 relaxation is the process by which the net magnetization (M) grows/returns to its initial maximum value (Mo) parallel to Bo.



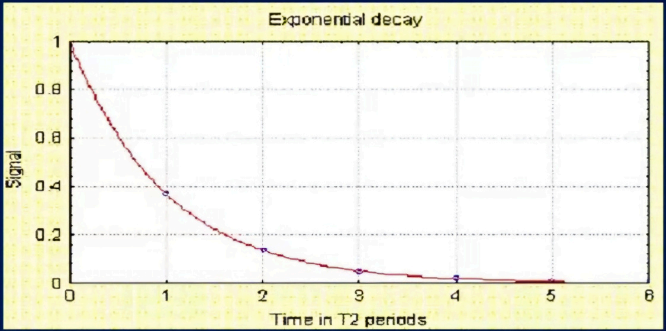
T1 RELAXATION TIME

Longitudinal relaxation is due to energy exchange between the spins and surrounding lattice (spin-lattice relaxation), re-establishing thermal equilibrium. As spins go from a high energy state back to a low energy state, RF energy is released back into the surrounding lattice.

The recovery of longitudinal magnetization follows an exponential curve. The recovery rate is characterized by the tissue-specific time constant T1. After time T1, longitudinal magnetization has returned to 63 % of its final value. With a 1.5 T field strength, T1 values are about 200 to 3000 ms. T1 values are longer at higher field strengths.

T2 RELAXATION TIME

T2 relaxation, also known as spin-spin relaxation or transverse relaxation, refers to the progressive dephasing of spinning dipoles resulting in decay in the magnetization in the transverse plane (Mxy). Following a radiofrequency pulse, this form of relaxation occurs with the time constant T2, where T2 is the time it takes for the transverse magnetization vector to decay to 1/e or 37% of its initial magnitude. T2 relaxation occurs due to tissue-particular characteristics, primarily those that affect the rate of movement of protons, most of which are found in water molecules.

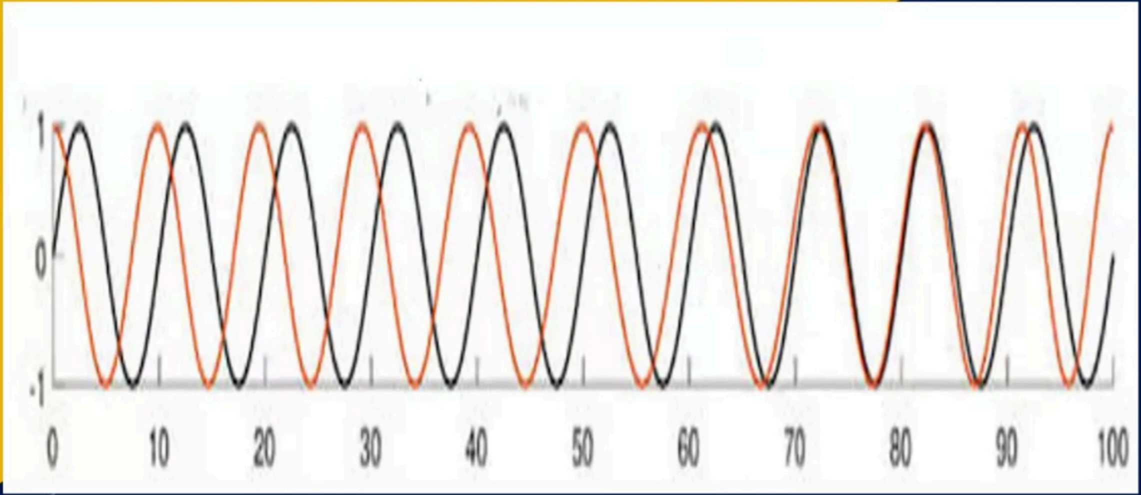


T2 RELAXATION TIME

Transverse relaxation results from spins getting out of phase. As spins move together, their magnetic fields interact (spin-spin interaction), slightly modifying their precession rate. These interactions are temporary and random. Thus, spin-spin relaxation causes a cumulative loss in phase resulting in transverse magnetization decay. Transverse magnetization decay is described by an exponential curve, characterized by the time constant T2. After time T2, transverse magnetization has lost 63 % of its original value.

T2 is tissue-specific and is always shorter than T1. Transverse relaxation is faster than longitudinal relaxation. T2 values are unrelated to field strength.

RESONANCE



RESONANCE

Resonance is the occurrence of a vibrating object causing another object to vibrate a higher amplitude. Resonance happens when the frequency of the initial object's vibration matches the resonant frequency or natural frequency of the second object.

Resonance enables the protons to absorb enough energy from the RF pulse to rotate their axes away from the B0 field, so that the MRI scanner can measure it.

RESONANCE

In practical terms, it allows for the efficient transfer of energy, the tuning of musical instruments, the design of efficient electrical circuits, and the prevention of structural damage from vibrations.

The significance of the nuclear precession is that it causes the nucleus to be extremely sensitive, or tuned, to RF energy that has a frequency identical with the precession frequency (rate).

This condition is known as resonance and is the basis for all MR procedures. NMR is the process in which a nucleus resonates, or "tunes in," when it is in a magnetic field.

Resonance is fundamental to the absorption and emission of energy by many objects and devices. Objects are most effective in exchanging energy at their own resonant frequency. The resonance of an object or device is determined by certain physical characteristics.