The Physics of MRI Scans

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Introduction

Magnetic resonance imaging (MRI) is an imaging technique used primarily in medical settings to produce high quality images of the inside of the human body. MRI is based on the principles of nuclear magnetic resonance (NMR), a spectroscopic technique used by scientists to obtain microscopic chemical and physical information about molecules. MRI started out as a tomographic imaging technique, that is it produced an image of the NMR signal in a thin slice through the human body.
Most of the human body is made up of water molecules, which consist of hydrogen and oxygen atoms. The MRI machine does not see the oxygen molecule, only the Hydrogens. At the center of each hydrogen atom, there is an even smaller particle called a proton. Protons are like tiny magnets and are very sensitive to magnetic fields. The MRI machines used properties of the protons to create an image.

The magnetic force field exerted from the MRI machine onto the Hydrogen protons pull the water molecules towards the machine. However, there is then radio frequency that causes the protons to flip to a different nuclear spin. The frequency required to cause the flip and the amount of time it takes to return to its original nuclear spin—this is called the signal—is recorded and used to make the image. (This process is also known as resonance and relaxation)
Spin Physics

MRI mechanism follow the law of quantum physics which study extremely small particles. So according to the laws of quantum physics, hydrogen nuclei have a property called spin, which can be 'oriented' in certain ways.

The MRI machine does not simply identify the hydrogen in the water. It has to irritate the hydrogen proton first then detect their presence from their responses. As its name implies, MRI uses magnets and it produces a magnetic field into which we put the patient.
Spin Physics

The strong magnetic field makes the spins of the hydrogen nuclei line up along the magnetic field. Some of the hydrogen nuclei line up in the direction of the magnetic field and other hydrogen nuclei line up opposite to the direction of the magnetic field. After the magnetic field has made the nuclear spins line up, there will be slightly lower energy nuclei than high energy nuclei. It is the behavior of these low energy hydrogen nuclei that make MRI possible. The MRI machine has a special coil of wire that is there for the purposes of producing the needed energy to 'irritate' the low energy hydrogen nuclei. Therefore this energy used is often called "radio frequency" energy (RF energy) and the coil is often called an radio frequency coil (RF coil).
Radio Frequency

Radiofrequency coils are two major parts of the radiofrequency (RF) system in the MRI hardware. The signal that is produced by the MRI machines is a result of radio frequency coils. In the MRI machines, there are electromagnetic coils that are electrical conductors, usually a wire, which are in the shapes of a spiral, coil, or helix: Electrical currents are passed through the wire of the coil to generate a magnetic field. The electrical currents creates a circular magnetic field around the conductor due to Ampere’s law. There are advantages to using a coil shape because the shape increases the strength of the magnetic field produced by the current. The more turns there are in the conductor (the wire in this case) the stronger the magnetic field. The receiver coil picks up the RF electromagnetic relaxation produced by nuclear relaxation inside the subject.
How Does it Work? (Summary)

- Protons are lined up in the same direction once under a powerful scanner magnet.
- Burst of radio waves are released which knocks the protons out of alignment and once turned off, sends out radio frequency signals.
- Signals provide exact location of protons in the body.
- MRI distinguish between the various types of tissue in the body, because the protons in different types of tissue realign at different speeds and produce distinct signals.
- The signals from the millions of protons in the body are combined to create a detailed image of the inside of the body.
The uses of MRI and its limitations

MRI machines are essentially proton NMR which image the concentration of protons. MRI takes advantage of the fact that we are mostly composed of water; humans are approximately 80% water. So MRI is particularly well suited for the imaging of soft tissue, like the brain, eyes, and other soft tissue structures in the head as shown at left. However, the bone of the skull do not have many protons, so it shows up dark. Also the sinus cavities image as a dark region.

In short, MRI is a very useful imaging tool, but there are limitations. In areas such as the bones of the skull or sinus cavities x-rays may be more useful since they take advantage of the different densities in the human body.
Video

https://www.youtube.com/watch?v=pGcZvSG805Y
The End!

Thank you