Theoretical lecture

The Hardware of MRI and Magnet

The Hardware of MRI

Hardware in an MRI system mainly includes (figure1):

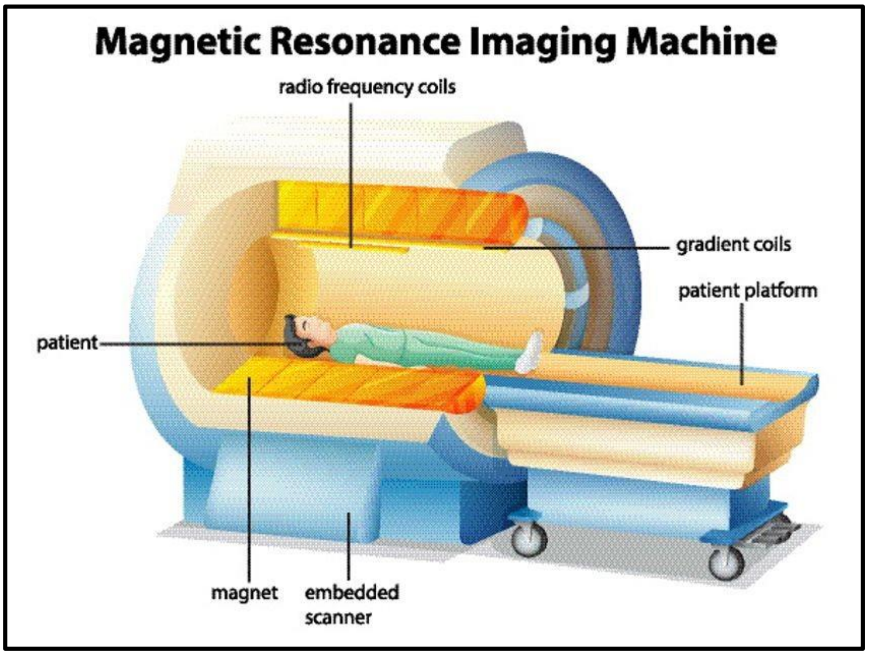

Figure 1: The major components of MRI system.

1- Gantry:

The gantry consists of

- **Main magnet:** The most important and biggest part of the MRI device is a magnet, used to generate a static magnetic field and allow the device to produce a high-quality image.
- **Gradient assembly:** To produce a gradient magnetic field, a magnetic field with different densities in a direction in space, and this variation in field density is added to the main magnetic field, which is far more powerful.

- **Radio-frequency (RF) coil:** To produce radiofrequency waves that penetrate the body of the patient. Figure 2 illustrates the cross-section of the MRI device gantry.

2- Patient table: This component simply slides the patient into the MRI machine.

3- Computer system: This is a very sensitive device that easily detects the RF signals emitted by a patient's body while undergoing examination and feeds this information into the computer system.

1. Magnets

The magnet is the heart of the MRI system and the patient is placed inside the magnet, surrounded by a set of coils connected to an RF generator, figure3.

The imaging process requires a magnetic field that is uniform and static and sufficient size to accommodate an adult human being. Magnet used to generate a static magnetic field.

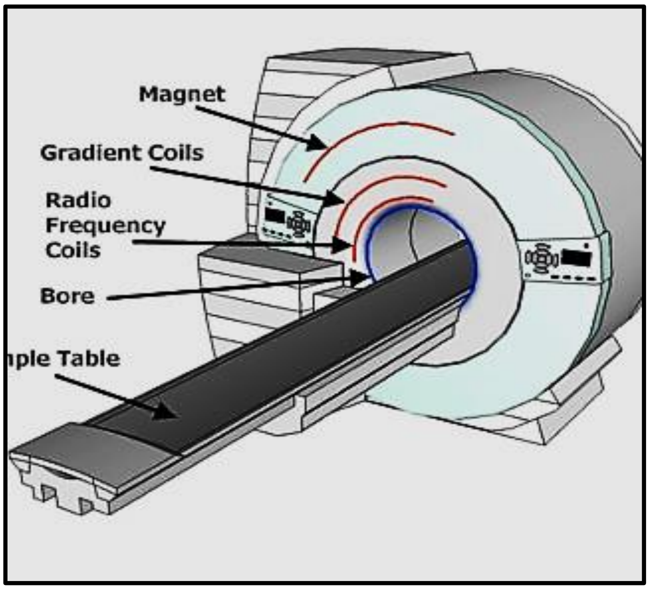

Figure3: Schematic diagram of MRI machine.

Static Magnetic Field

Static magnetic fields are constant of **fields**, which do not change in intensity or direction over time, in contrast to low and high-frequency alternating **fields**. Hence, they have a frequency of 0 Hz.

This main magnetic field is generated by a large electric charge spinning on a helium-cooled on superconducting coil.

Earth's magnetic field (30-60 µT), while MRI magnets are suitable for scanning humans (1.5-7 T).

Patients with implants, prostheses, pacemakers, heart valves, etc. should be away from the MRI area, where fringe fields are > 0.5 mT.

The static magnetic field floods the entire patient's body. In addition to the main part of the device's installation, the huge magnet generates a static magnetic field.

Types of Magnets

According to the way the field is generated; there are three types of magnets:

a. Permanent magnet.
b. Resistive electromagnet.
c. Superconductive magnet.

a. Permanent Magnet

Permanent magnets are made from a material that is magnetized and creates its own persistent magnetic field. *The permanent magnet* consists of two flat opposing pole pieces (Iron alloys, Al, nickel, and cobalt).

Permanent magnets have predominantly been designed with a vertical field format, with the field constrained between the top and bottom pole faces (figure 4).

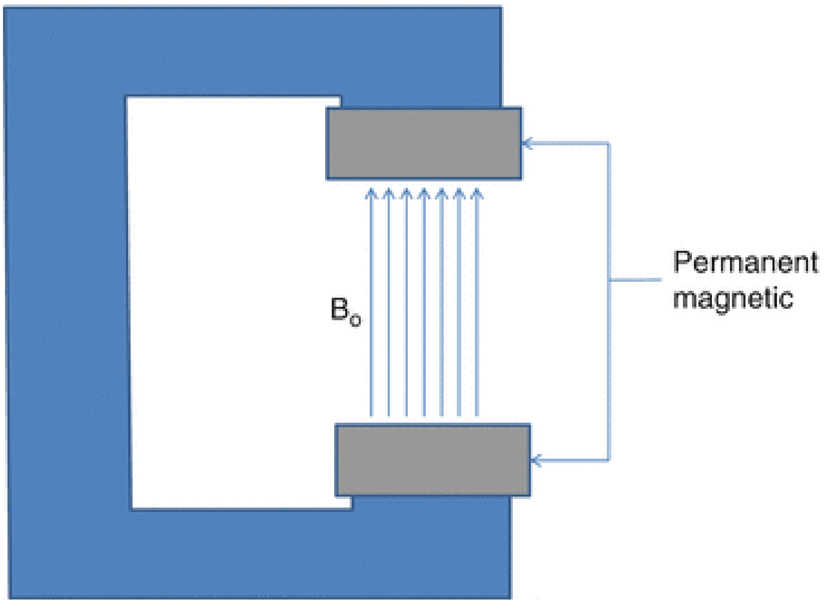

Figure 4: C-shaped permanent magnet

A recent innovation has a permanent magnet with a horizontal field, allowing patients to be positioned in the upright position, which is of value for examining joints.

Properties of the permanent magnet:

- It is expensive, but cheaper in running cost.
- It requires no power.
- Cannot be switched off.
- Produce vertical magnetic field up to 0.3 T.
- No claustrophobia issue, suitable for children.
- The permanent magnets are very heavy and depend on the choice of magnetic material. For example; a 0.2 T whole-body magnet

constructed from iron might weigh 25 tons, while the weight of a similar magnet built from a neodymium alloy could be 5 tons.

b. Resistive Electromagnet

A resistive electromagnet has a set of coils run by a direct current with 50–100 kW (Al or copper) (figure 5). Electromagnets reduce the electrical current requirement of resistive magnets by incorporating a ferromagnetic core and also by providing greater stability and minimizing cooling requirements.

Properties of resistive electromagnet:

- It produces heat and requires water cooling.
- It can provide both vertical and horizontal magnetic fields up to 0.5 T.
- Has no fringe field.
- It can be switched off during an emergency.
- Cheapest, smaller, and weighs 2 tons.

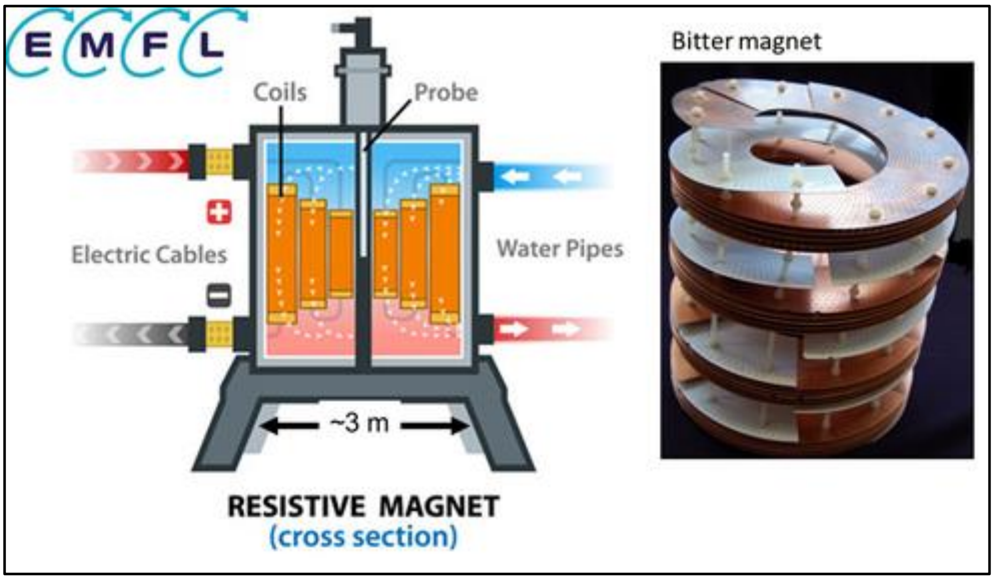

Figure 5: Cross Section of Resistive Magnet.