Theoretical lecture

The Hardware of MRI and Magnet

The Hardware of MRI

Magnetic resonance imaging (MRI) is comprehensively applied in modern medical diagnosis and scientific research for its superb soft-tissue imaging quality and non-radiating characteristics. Hardware in an MRI system which mainly includes (figure1):

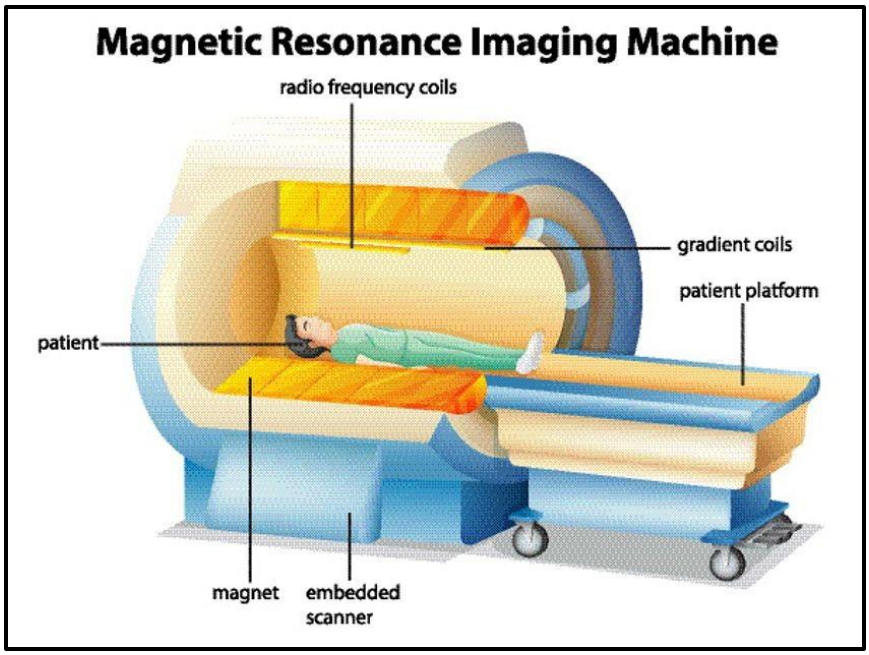

Figure 1: The major components of MRI system.

1- Gantry: consist of

- **Main magnet:** The most important and biggest part of the MRI device is magnet, used to generate static magnetic field and allows to device to produce high quality image.
- **Gradient assembly:** To produce gradient magnetic field, magnetic field with different density 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 illustrate the cross section of the MRI device gantry.

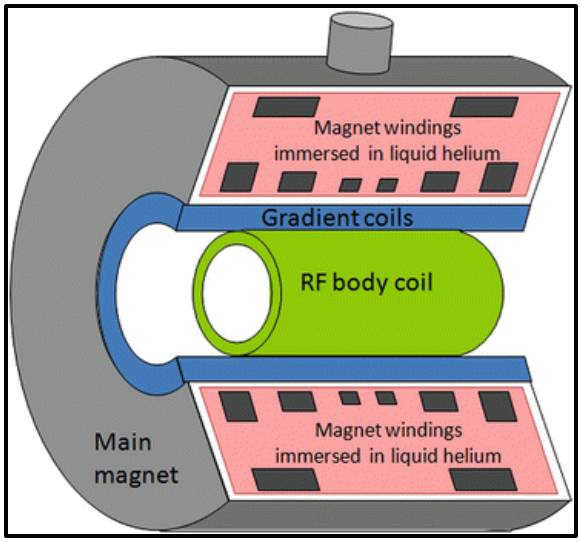

Figure2: Cross section of MRI gantry.

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

3- Computer system: 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 MR system and the patient is placed inside the magnet, surrounded by set of coils connected to RF generator, figure3.

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

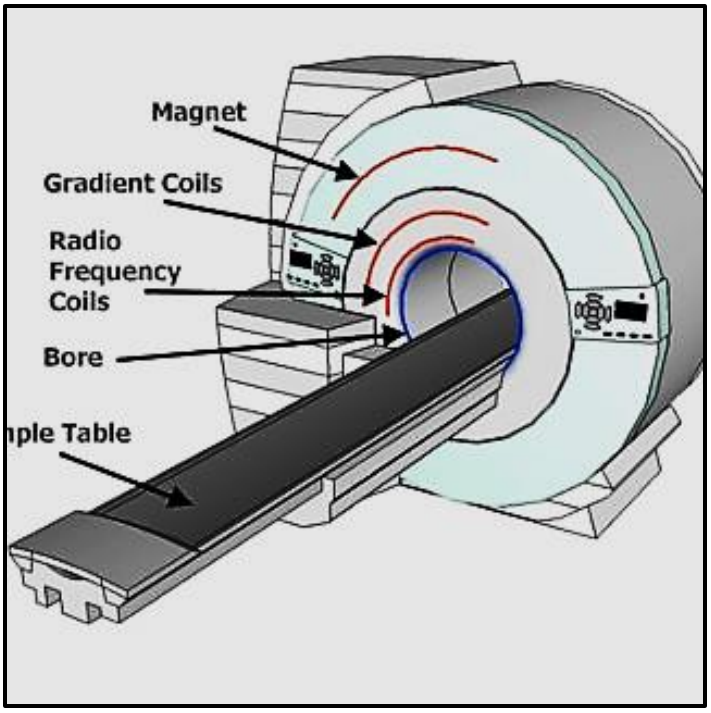

Figure3: Schematic diagram of MRI machine.

Static Magnetic Field

Static magnetic field are constant **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 magnet field generated by a large electric charge spinning on a helium cooled on super conducting coil.

Earth's magnetic field (30-60 microtesla), while MRI magnet suitable for scanning humans (1.5-7 tesla).

The limit for hospital staffs are:

1. Pregnant patients should not be exposed > 2.5 T.
2. Whole body < 2T.
3. Limbs < 5 T.

4. Patients with implants, prosthesis, pacemakers, heart valves, etc. should be away from 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 that generates a static magnetic field, but there is another type of magnet, The second type of a magnet that generates a gradient magnetic field, its intensity from 180 gauss to 270 gauss, and this is undoubtedly a very small magnetic field compared to static magnetic field. Its function and the role of the gradient magnetic field will be explained later.

Types of Magnet

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

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; this design requires a flux return path (figure 4).

The magnets are very heavy and cannot be switched off, but have a small stray field. A recent innovation has been a permanent magnet with a horizontal field, allowing patients to be positioned in the upright position, which is of value for examining joints.

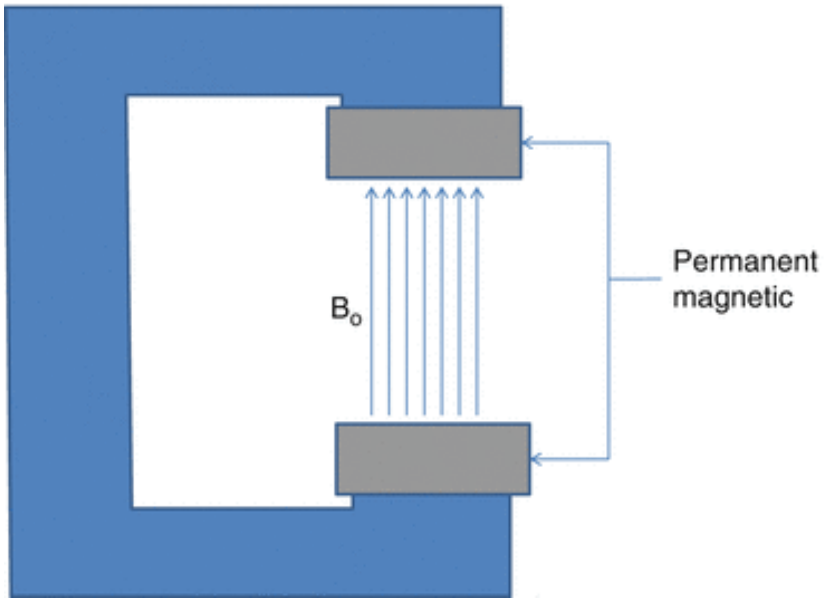

Figure 4: C-shaped permanent magnet

Properties of The permanent magnet:

- It is expensive, but cheaper in running cost.
- It requires no power
- Use low strength, vertical magnetic field up to 0.3 T.
- No claustrophobia issue, suitable for children, aged, and interventional work.
- The weight of permanent MRI magnet generally is very high, and depends on the choice of magnetic material.
- Example; 0.2 T whole body magnet constructed from iron might weigh 25 tons, while the weight of similar magnet built from a neodymium alloy could be 5 tons.

b. Resistive Electromagnet

Resistive electromagnet has set of coils run by 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 require water cooling.

- It can provide both vertical and horizontal magnetic field up to 0.5T.
- Has no fringe field.
- It can be switched off during emergency.
- Cheapest, smaller, and weighs 2 ton.

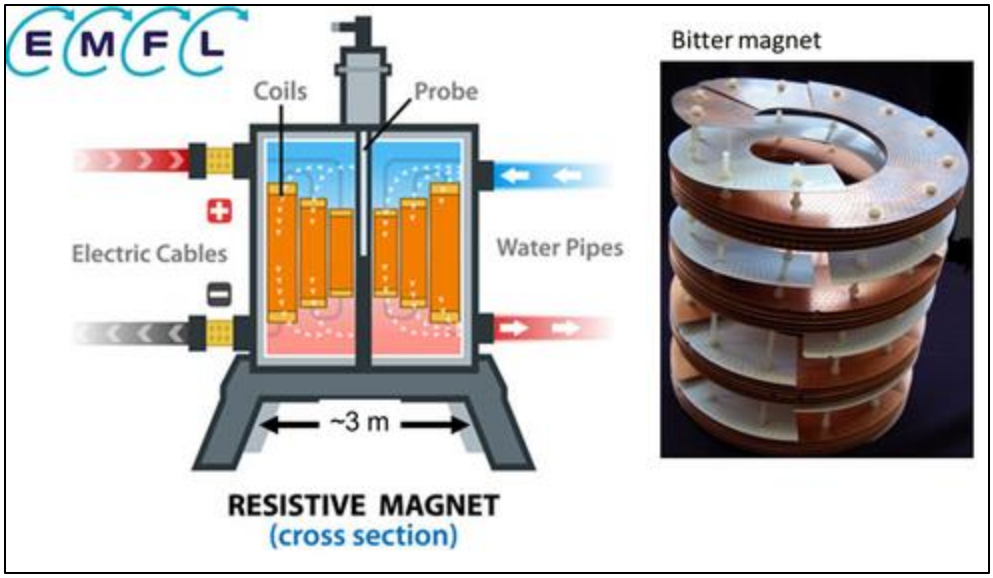

Figure 5: Cross Section of Resistive Magnet.

Questions:

Q1: list the main components of the MRI hardware and explain one of them?

Q2: define the static magnetic field?

Q3. What is the design of permanent magnet?

Q4: list five properties of the resistive electromagnet?

Q5: what are the disadvantages of permanent magnet?