



Magnetism

Lecture 6

Types of magnets

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A magnet is an object that has a magnetic field capable of attracting certain metals and other magnets. There are four main types of magnets: permanent magnets, temporary magnets, electromagnets, and natural magnets.

Permanent Magnet:

A permanent magnet is the most common type of magnet. It can retain its magnetic properties indefinitely without any external energy source. Examples include refrigerator magnets and ceramic magnets.

Permanent magnets, which can either be natural products (known as natural magnet stones) or man-made (the strongest being neodymium magnets), have wide hysteresis loops, high coercivity, and strong stability. These materials can maintain a constant magnetic field once magnetized.

In practical applications, permanent magnets operate in the deep magnetic saturation and demagnetization regions in the second quadrant of the hysteresis loop after magnetization. Permanent magnets should have a large coercive force (Hc), remanence (Br), and maximum magnetic energy product (BH)_{max} to ensure maximum magnetic energy storage and stable magnetization.

There are several types of permanent magnets.

Neodymium magnets are permanent magnets made from neodymium, iron, boron, and other elements. They have extremely high magnetic energy products and coercive force, making them one of the strongest permanent magnetic materials in the world.



2 .Samarium-Cobalt Magnet (SmCo) :

The Samarium-Cobalt magnet is a type of rare-earth permanent magnetic material made primarily from samarium (Sm) and cobalt (Co) through a powder metallurgy process. It has a high magnetic energy product, strong coercive force, and excellent temperature stability, allowing it to maintain good magnetic properties even in high-temperature environments.



3 .Alnico Magnet:

Alnico magnets are composed of metallic elements and are widely used as permanent magnets due to their high coercive force and good magnetic properties. This iron-based alloy consists mainly of aluminum (Al), nickel (Ni), cobalt (Co), and small amounts of other trace metals.



4 .Sintered Ferrite Magnet:

Sintered ferrite is a type of magnetic material produced by sintering iron oxide (mainly Fe_2O_3) with other metal oxides (such as BaO , SrO , etc.) through a ceramic process. It belongs to the category of hard magnetic materials, characterized by a high magnetic energy product and strong coercive force, allowing it to retain magnetism even after the external magnetic field or electric current is removed.



5 .Rubber Magnet:

A rubber magnet is a soft, flexible, and bendable magnet made by mixing magnetic powder materials (such as ferrite or NdFeB) with flexible substances like rubber or plastic, followed by extrusion, calendaring, or injection molding processes. It can be easily shaped into various forms and sizes and possesses a certain degree of flexibility and softness.



Classification of Permanent Magnet Process

1. Bonded NdFeB

Bonded NdFeB is a magnet made by mixing magnetic NdFeB powder and a binder through either compression molding or injection molding. Bonded magnets have high dimensional accuracy and can be formed into relatively complex magnetic components. They also feature one-time molding properties and multi-pole orientation.

2. Sintered NdFeB

Sintered NdFeB is a high-performance permanent magnetic material, mainly composed of the rare-earth element neodymium (Nd), the metallic transition element iron (Fe), and the non-metallic element boron (B). It is manufactured using powder metallurgy techniques, including steps of mixing, melting, crushing, pressing, sintering, and heat treatment of these elements in precise proportions. Sintered NdFeB has extremely high magnetic energy products, high stability, and high coercivity, making it one of the strongest permanent magnet materials currently available.

3. Injection-Molded NdFeB

Injection-molded NdFeB is a special type of permanent magnetic material that combines the advantages of injection molding technology with NdFeB magnetic materials. It is manufactured by mixing NdFeB magnetic powder with a high-molecular-weight polymer, then producing various complex-shaped magnetic components through the injection molding process. Injection-molded NdFeB not only retains the high magnetic properties of NdFeB but also offers good operational performance and corrosion resistance.

Applications of Permanent Magnets

Permanent magnets have a wide range of applications due to their ability to maintain magnetization, making them widely used across many fields and industries.

They are extensively used in various areas such as electronics, electrical engineering, machinery, transportation, medical equipment, and daily-use products. Examples include:

- Permanent magnets in loudspeakers and telephone receivers.
- Magnetic systems in electromagnetic meters.
- Magnetic poles in generators and permanent-magnet motors.
- Permanent-magnet devices used in machinery, such as permanent-magnet chucks for surface grinders.

- Magnetic suspension systems and magnetic bearings.
- Magnetic separation systems, magnetic ore separation, and magnetic water purification systems.
- Magnetrons and magnetic systems for proton accelerators.



Temporary Magnet

A temporary magnet, also known as a soft magnetic material or temporary magnet, is made from a ferromagnetic material that can be magnetized for a short period by an external magnetic field but loses its magnetic properties once the external field is removed.

These materials are characterized by low coercivity (i.e., a weak ability to resist demagnetization), so their magnetic state can easily change with variations in external conditions. Common temporary magnets include pins and paperclips, which can be picked up or moved using a strong magnet.

Performance of Temporary Magnets

1. **Low Coercivity:** They are easy to magnetize and demagnetize.

- 2. High Magnetic Permeability:** They can effectively guide and concentrate magnetic fields.
- 3. Low Retentivity:** When the external magnetic field is removed, the residual magnetism is very low.
- 4. Good Conductivity:** Some temporary magnetic materials also exhibit good conductivity.

Applications of Temporary Magnets

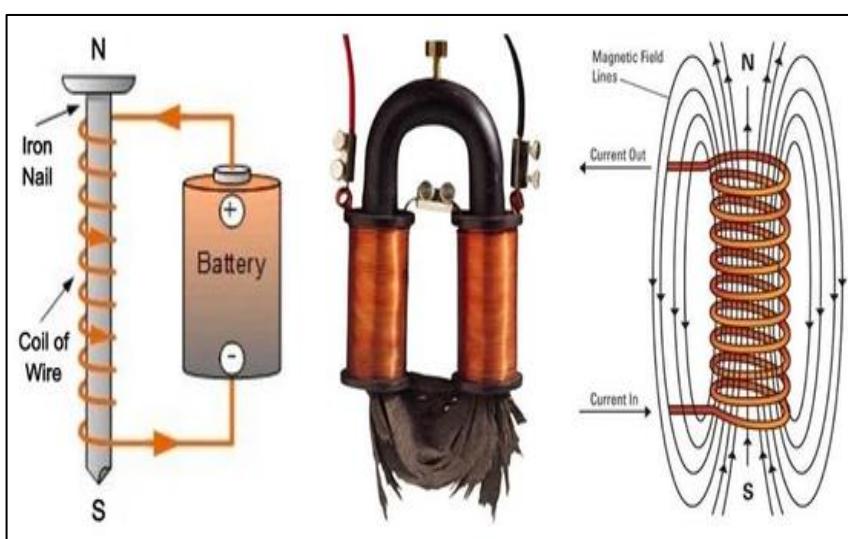
Temporary magnets have a wide range of applications in industry, technical equipment, and daily life. They are mainly used in the manufacture of electromagnets, transformers and inductors, sensors and measuring instruments, automotive and aerospace equipment, medical devices, and more.

Electromagnet

Electromagnets are temporary magnets created by passing electricity through a coil of wire to generate a strong magnetic field. This type of magnet is used in many consumer electronic devices, such as electric motors and loudspeakers.

An electromagnet consists of a coil and an iron core. A conductor coil of appropriate strength is wound around the iron core. When current flows through this coil, it generates a magnetic field around the iron core, making the electromagnet magnetic. It is also called an electric magnet.

Typically, the electromagnet is made in the shape of a bar or horseshoe to facilitate magnetization of the iron core. Additionally, to allow the magnetization to disappear immediately when the current is turned off, soft iron or silicon steel with faster demagnetization properties is often used. Such an electromagnet becomes magnetic when powered and loses its magnetism when the power is switched off.



Working Principle of an Electromagnet

Faraday's law of electromagnetic induction states that when magnetic flux passes through a conductor loop, an induced electromotive force is generated in the loop. In an electromagnet, when current flows through a coil, it generates a magnetic field. This magnetic field interacts with the iron core, magnetizing the core.

Once the iron core is magnetized, it becomes a temporary magnet with a north and south pole. The strength of the magnetic field depends on the current intensity, the number of coil turns, and the material and shape of the core.

When the electromagnet's core is magnetized, it can attract or repel other magnetic objects. The magnetism of the electromagnet can be controlled by turning the current on or off. When the current stops, the magnetic field disappears, and the core loses its magnetism.

The working principle of an electromagnet relies on the interaction between current and the magnetic field. This interaction allows electromagnets to play a vital role in many applications, such as electromagnetic cranes, motors, relays, solenoid valves, and more.

Electromagnets in Daily Life

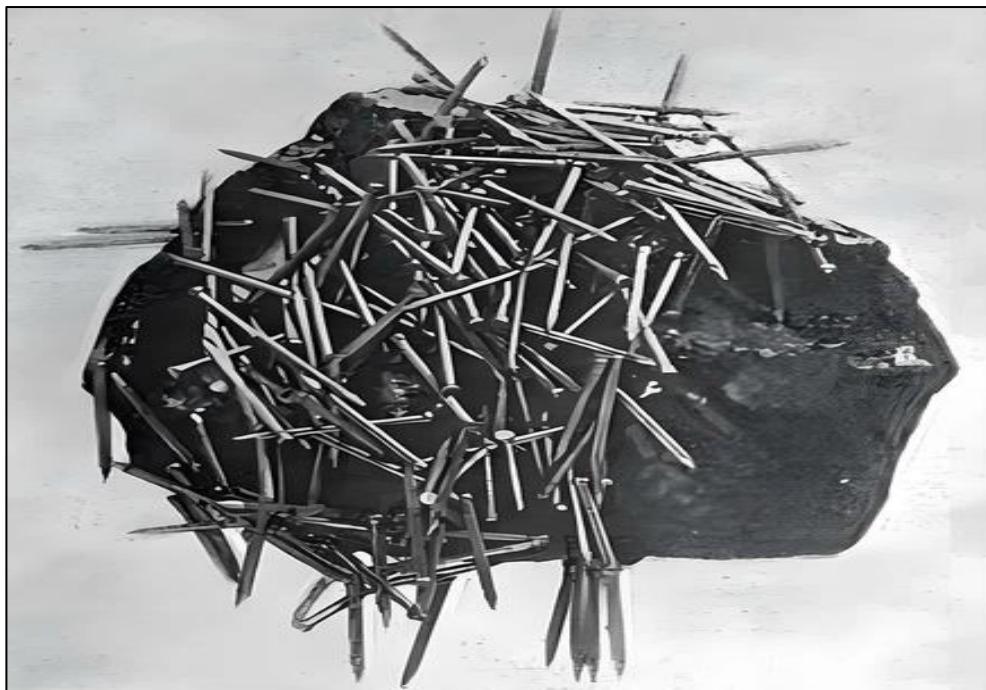
There are many electromagnets in our daily lives, widely used in electromagnetic cranes, electromagnetic locks, electromagnetic relays, solenoid valves, loudspeakers, electric toys, Maglev trains, electric generators, telephones, automated control equipment, packaging machines, medical devices, food processing machinery, textile machines, and more.

Electromagnets perform various useful functions by controlling the current intensity and magnetic field, such as attracting or repelling iron objects and enabling mechanical movements like linear motion, rotation, and oscillation. They play an indispensable role in industry and modern life.

Natural Magnet

A natural magnet is one that occurs naturally in the environment and can be found in iron ore deposits. It is also referred to as a lodestone or magnetite. Natural magnets can attract magnetic metals such as iron, nickel, and cobalt. They are found in the Earth's

environment and usually have strong magnetism. Natural magnets are among the oldest magnetic materials discovered and used by humans.



Natural magnets were discovered and used by humans in ancient times and have had important applications in history, especially in navigation. For example, the ancient Chinese compass used the magnetism of natural magnets to indicate direction.

Unlike artificial electromagnets, the magnetism of a natural magnet is determined by its internal atomic structure and electron arrangement, and no external power source is needed to maintain its magnetism. However, the magnetism of natural magnets is relatively weak and usually not as strong or adjustable as that of artificial electromagnets.

Although most magnets used in modern technology are artificial, natural magnets are still used in some areas, such as certain types of education and scientific research, crafts and decorations, magnetic therapy products, and for demonstrating the concept of magnetic fields.

As an ancient magnetic material, natural magnets hold not only historical significance but also certain practical value in modern society. Although their magnetic strength is not as high as modern artificial permanent magnets, their natural beauty and unique historical importance have earned them a place in education, research, and art.