

Topic 13: Magnetism

Source: *Conceptual Physics* textbook, lab book, and CPO textbook and lab book

Types of Materials: Textbooks, lab books, worksheet, demonstration, activity/lab, websites/videos, and good stories

Building on: Previous to this topic, force, force fields, vectors, and charges in motion have been studied. Since magnetism is caused by charges in motion, atomic charge movement or charges drifting down a wire can explain magnetism's presence. If students do simple demonstrations or experiments, the interconnection of moving electric charge and magnetism can be observed. The electric and magnetic field interaction and some kind of law can predict the direction of force on moving charge or wires, that being the right-hand rule (the vector cross product can be passed with freshman!!!).

Leading to: When a student studies magnetic fields (vectors at work) and the cause of magnetism, this knowledge, used with electricity knowledge, allows people to make electric generators for a major source of our energy needs. Some other applications include the building of a particle accelerator to find out about the building blocks of the universe and the force laws, the building of electronic devices like the CRT television sets that use magnets to direct the e- beam; or, in other words, a lot of practical applications can be found.

Links to Physics: Magnetism in itself has direct applications like the electromagnet in a junk yard to lift cars, the magnet field in older TV sets to direct the electrons to form a picture, the magnets at Fermilab to direct and focus the charged beam, and don't forget Mr. Whiskers, the game of putting hair and a mustache on a toy face! When combined with electricity, electric generators can be made and understood; electromagnetic waves like radio waves can be created and medical machines like the MRI (Magnetic Resonant Imaging) can be made and used for our good.

Links to Chemistry and Biology: Chemistry uses the atomic spectrum (emission spectrum) to analyze samples. The different types of electromagnetic spectrum are studied and used including visible light; X-rays; ultraviolet; and cosmic rays are used as descriptors for causing DNA mutation. Biology uses the spectrum to do photosynthesis, and X-rays for medical purposes. Physics uses microwaves for communication and cooking, radio waves for radio, and infrared for garage door openers and TV remotes.

Materials:

- (a) Hewitt
 - 1. 3-D Magnetic Field
 - 2. You're Repulsive
 - 3. Jump Rope Generator
- (b) Hsu
 - 1. Magnetism
 - 2. Electromagnets
 - 3. Electromagnetic Forces
 - 4. Electromagnetic Induction
 - 5. The Magnetic Field
 - 6. Using Fields
- (c) My Lab
Right-Hand Rule and Charges in Motion*
- (d) Worksheet
Magnets*
- (e) Demonstration
Magnets at Work*
- (f) Videos and Websites
<http://web.mit.edu/smcs/8.02/> - 25k
(Free source of lecture/demos on all physics topics including magnetism by MIT professor)
- (g) Good Stories
 - 1. Magnetism – The Early Years
 - 2. Hans Christian Oersted (1777-1851)
 - 3. William Gilbert (1544-1603) – The Father of Magnetism

Magnetism – The Early Years

There are many legends accounting for the discovery of magnets. One of the most common is that of an elderly shepherd named Magnes, who was herding his sheep in an area of northern Greece called Magnesia about 4,000 years ago. It is said that both the nails in his shoes and the meal tip of his staff became firmly stuck to the large black rock on which he was standing. This type of rock was subsequently called magnetite after either Magnesia or Magnes himself.

Stories of magnetism date back to the first century B.C. in the writings of Lucretius, and the magical powers of magnetite are mentioned in the writings of Pliny the Elder. Magnetite was surrounded in superstition and was considered to possess magical powers such as the ability to heal the sick, frighten away evil spirits and attract and dissolve ships made of iron.

Roger Bacon, in the thirteenth century, had gained a reputation as an alchemist and magician and was jailed by the church for his experiments with lodestones.

The first attempt to separate fact from superstition came in 1269 when a soldier named Peter Peregrinus wrote a letter describing everything that was known at the time about magnetite. It is said that he did this while standing guard outside the walls of Lucera, which was under siege. While people were starving to death inside the walls, Peter Peregrinus was outside writing one of the first scientific reports of magnetic properties.

It wasn't until the experiments of William Gilbert in 1600 that significant progress was made in understanding magnetism.

Hans Christian Oersted (1777-1851)

Oersted was born on a small Danish island near Copenhagen. There was no school in the town so he and his younger brother went to the homes of neighbors who taught the boys to read and write. Later the town surveyor taught them mathematics and the mayor taught them English and French. Later Hans worked in his father's pharmacy as a way to earn enough money to pursue a more formal education. At the age of twenty he earned a degree in pharmacy and at twenty-two a Doctor of Philosophy.

Oersted's discovery of the relation between electricity and magnetism is often described as the result of a lucky accident occurring during the course of a laboratory demonstration, when a platinum wire carrying an electrical current was brought near a magnetic compass causing the compass needle to deflect. Oersted claimed his only surprise was that the needle only deflected a small amount and at the time offered no explanation for the observation. Three months passed before Oersted continued his investigation. In that time he learned that the magnetic field was circular rather than spiral and that non-magnetic objects, when placed in the field, had no effect.

Oersted may not have been the first to discover that electricity and magnetism are related. He was, perhaps, preceded by Domenico Romagnosi eighteen years earlier. Romagnosi, an Italian legal scholar, had published similar observation in an Italian newspaper but was ignored by the scientific community.

In 1819 he befriended a poor fourteen-year-old boy, who over the years, had become another member of the family—Hans Christian Andersen, the famous Danish storyteller.

William Gilbert (1544-1603) – The Father of Magnetism

Gilbert was born to wealthy middle-class parents in Gloucester, England. He studied medicine and rose to the position of president of the Royal College of Physicians. William Gilbert also became the royal physician to Queen Elizabeth I and James I of England. When the queen died in 1603, her only patronage grant was to Gilbert to enable him to pursue his hobby, physics. Unfortunately, he died a few months later of plague. Contemporaries of Gilbert included Johannes Kepler, Tycho Brahe, and William Shakesphere.

Prior to Gilbert all that was known of electricity and magnetism was what the ancients knew. These included myths such as: Does garlic affect a compass needle? Did the pole star attract it (as Columbus had thought)? Will ships nails be pulled from the hulls towards mountains of lodestone? Gilbert was rather critical of early writings due to their lack of supporting experimental data. He spent nearly twenty years pioneering the experimental method and was the first to explain the magnetic compass. To him we owe the term “electricity.” He invented the electroscope, investigated conductors and insulators and was also responsible for the terms “electric force” and ” magnetic pole.” His “orb of virtue” describes the space around a magnet where forces act—a magnetic field.

Gilbert invented instruments to measure magnetic declination and dip and proposed using these values to determine latitude and longitude. This was an idea that Sir Edmund Halley later explored but abandoned due to the earth’s changing magnetic field.