

4.1 Permanent Magnets, Poles, Field Direction



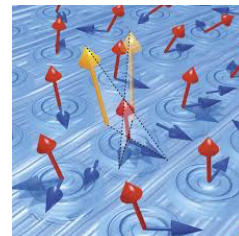
Magnets

Magnetic objects attract others due to electronic interactions!

Permanent Magnets: crystalline structure affixes electrons at certain positions in the lattice.

Electromagnets: electron movement makes a magnetic field (strength proportional to current).

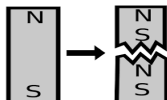
Electron Spin



Polarity

Magnets have a dipole: a North and South end.

Monopoles are impossible: a cut magnet has north and south ends.



Historically, Earth's field established polarity: magnets had north and south-seeking ends.

(Attraction/repulsion ceramic magnet Demo. - give them out)

Ancient people used magnetite (lodestone) as a compass: it aligned with the Earth's magnetic field, always pointing North.

(Hanging magnet demo.)

Rabbit Holes!



Magnetite

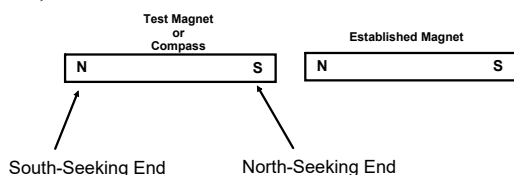
The process by which lodestone is created has long been an open question in geology. Only a small amount of the magnetite on the Earth is found magnetized as lodestone. Ordinary magnetite is attracted to a magnetic field like iron and steel is, but does not tend to become magnetized itself; it has too low a magnetic coercivity (resistance to demagnetization) to stay magnetized for long. Microscopic examination of lodestones has found them to be made of magnetite (Fe_3O_4) with inclusions of maghemite (cubic Fe_2O_3), often with impurity metal ions of titanium, aluminium, and manganese. This inhomogeneous crystalline structure gives this variety of magnetite sufficient coercivity to remain magnetized and thus be a permanent magnet.

The other question is how lodestones get magnetized. The Earth's magnetic field at 0.5 gauss is too weak to magnetize a lodestone by itself. The leading theory is that lodestones are magnetized by the strong magnetic fields surrounding lightning bolts. This is supported by the observation that they are mostly found near the surface of the Earth, rather than buried at great depth.

Monkey Wrench

Realize: a magnet's "north-seeking" end is the south pole, and the "south-seeking" end is the north pole.

Since opposites attract, north ends align with south ends, and vice versa.



Magnetic Materials

Three ways materials respond to a magnet:

1. Ferromagnetism (in iron): a material's atomic structure gives it a magnetic moment.

These materials can have an induced magnetic moment by magnetic contact.

(screwdriver demo).



Above the Curie Temperature, internal structure alters, eliminating the magnetic moment. (Demo. - Heat up damaged supermagnet)

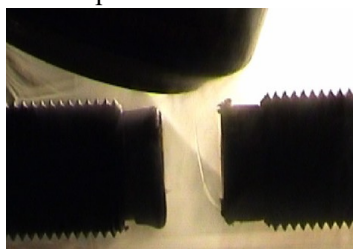
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Magnetic Materials

2. Paramagnetism: temporary configuration in a material causing an attraction to a magnetic field.

Removing the magnet disrupts the material's magnetic moment.

Liquid oxygen
attracted to
a magnet.



Magnetic Materials

3. Diamagnetism: a magnetic field induces an opposite field in a material, causing repulsion.

A really weak interaction: measurable by sensitive equipment.

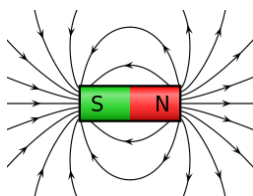
Levitating
Pyrolytic Carbon



Magnetic Fields

Magnetism is a fundamental vector force; fields are designated by the symbol 'B'.

The direction of B at a point is the direction a compass' north pole (south-seeking) points if placed there.



B field lines are drawn from North to South; the closer the lines, the stronger the field.

Iron filings demo.

The Earth's Magnetic Field

Moving fluids (molten iron alloys in the outer core) in the Earth cause a magnetic field.

This protects us from solar particle bombardment: charged particles are funneled to the poles where they manifest as the aurora. With no geomagnetic field, the atmosphere would be stripped away!

FYI: the geographical north end of the Earth is actually the magnetic south pole (for now).



Homework 4.1

Problems 4.1 in your Booklet
Due: Next Class