Magnetism

Unit: Magnetism & Electromagnetism

MA Curriculum Frameworks (2016): N/A

AP® Physics 2 Learning Objectives: 2.4.C.1, 2.D.2.1, 2.D.3.1, 2.D.4.1, 4.E.1.1

Mastery Objective(s): (Students will be able to…)

- List and explain properties of magnets.

Success Criteria:

- Explanations account for observed behavior.

Language Objectives:

- Explain why we call the ends of a magnet "north" and "south".

Tier 2 Vocabulary: magnet

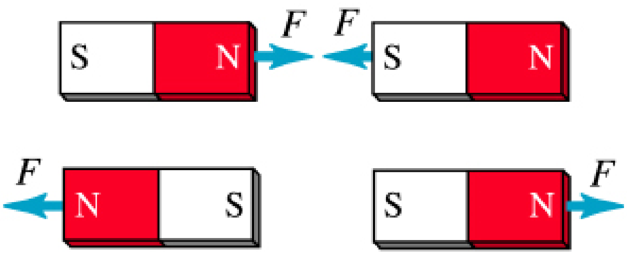
Labs, Activities & Demonstrations:

- neodymium magnets
- ring magnets repelling each other on a dowel
- magnets attracting each other across a gap

Notes:

magnet: a material with electrons that can align in a manner that attracts or repels other magnets.

A magnet has two ends or "poles", called "north" and "south". If a magnet is allowed to spin freely, the end that points toward the north on Earth is called the north end of the magnet. The end that points toward the south on Earth is called the south end of the magnet. (The Earth's magnetic poles are near, but not in exactly the same place as its geographic poles.)All magnets have a north and south pole. As with charges, opposite poles attract, and like poles repel.



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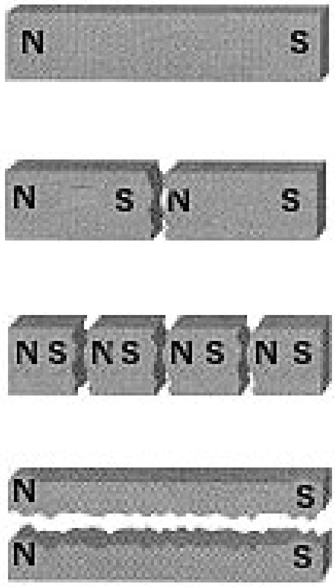
If you were to cut a magnet in half, each piece would be a magnet with its own north and south pole:



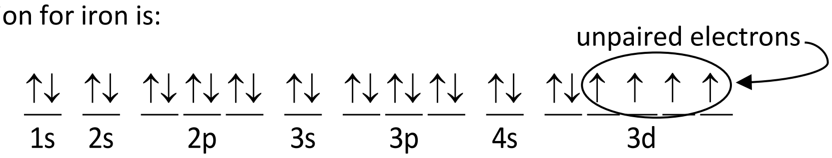
Electrons and Magnetism

Honors (not AP®)

Magnetism is caused by unpaired electrons in atoms. Electrons within atoms reside in energy regions called "orbitals". Each orbital can hold up to two electrons.

If two electrons share an orbital, they have opposite spins. (Note that the electrons are not actually spinning. "Spin" is the term for the intrinsic property of certain subatomic particles that is believed to be responsible for magnetism.) This means that if one electron aligns itself with a magnetic field, the other electron in the same orbital becomes aligned to oppose the magnetic field, and there is no net force.

However, if an orbital has only one electron, that electron is free to align with the magnetic field, which causes an attractive force between the magnet and the magnetic material. For example, as you may have learned in chemistry, the electron configuration for iron is:



The inner electrons are paired up, but four of the electrons in the 3d sublevel are unpaired, and are free to align with an external magnetic field.

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Magnetic measurements and calculations involve fields that act over 3-dimensional space and change continuously with position. This means that most calculations relating to magnetic fields need to be represented using multivariable calculus, which is beyond the scope of this course.

magnetic permeability (magnetic permittivity): the ability of a material to support the formation of a magnetic field. Magnetic permeability is represented by the variable μ. The magnetic permeability of empty space is $\mu_0 = 4\pi \times 10^{-7}\ \frac{\text{N}}{\text{A}^2}$.

diamagnetic: a material whose electrons cannot align with a magnetic field. Diamagnetic materials have very low magnetic permeabilities.

paramagnetic: a material that has electrons that can align with a magnetic field. Paramagnetic materials have relatively high magnetic permeabilities.

ferromagnetic: a material that can form crystals with permanently-aligned electrons, resulting in a permanent magnet. Ferromagnetic materials can have very high magnetic permeabilities. Some naturally-occurring materials that exhibit ferromagnetism include iron, cobalt, nickel, gadolinium, dysprosium, and magnetite (Fe_3O_4).

magnetic susceptibility: a measure of the degree of magnetization of a material when it is placed into a magnetic field.

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