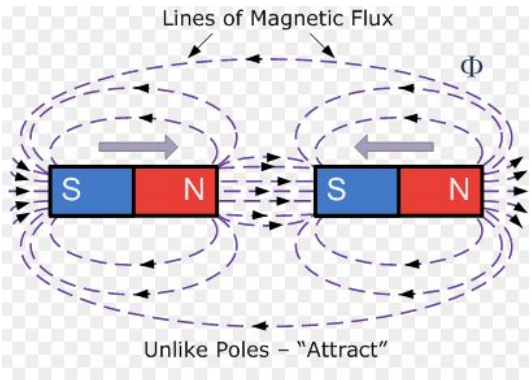
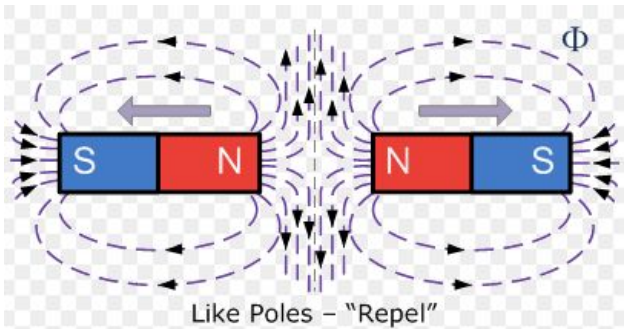
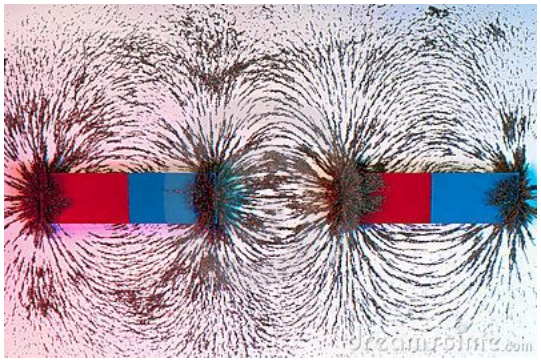
Magnets and Magnetism

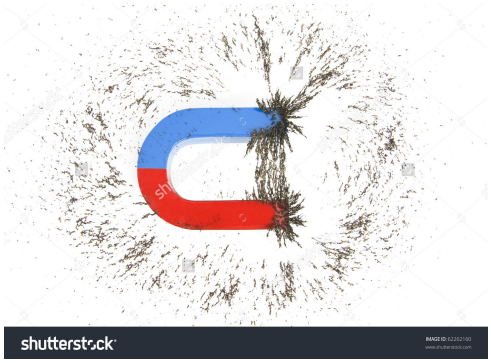
"The north and the south, You have created them" Psalm 89:12

- magnet: object capable of attracting materials such as some metals by magnetic force
- magnetism: property of attracting objects by magnetic force
- poles: regions of concentrated magnetism; north and south
  Law of magnetic poles: unlike poles attract each other, but like poles repel each other
  Magnetic poles always exist in pairs
- Magnetic field: region surrounding a magnet in which other objects are affected (ex: magnet near compass)
  Lines of flux: imaginary lines that indicate direction and strength of magnetic field; closest at poles, indicating the magnetic field is strongest at the poles; lines of flux continuous









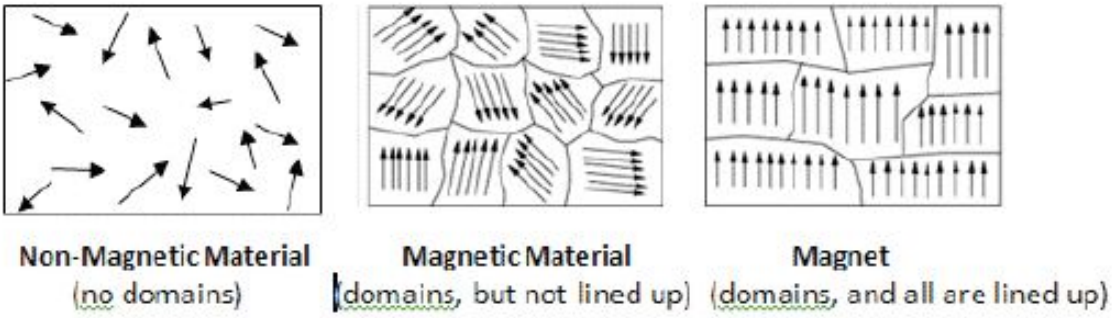
- Law of magnetic force: force between two magnetic poles is directly related to the product of the pole strengths and inversely related to the square of the distance:

$$F = \text{constant} \times \frac{\text{strength of pole}_1 \times \text{strength of pole}_2}{(\text{distance between poles})^2} \quad \text{OR} \quad F = \kappa \times \frac{\rho_1 \times \rho_2}{d^2}$$

- Magnetic force can act through air or space, but acts more strongly through certain materials
  Permeability: extent to which a material can absorb or channel lines of magnetic flux
  High - Fe, Co, Ni; low - Al, wood, air
  Placement of permeable material can increase or decrease magnetic force (steel can v. wood table)

Understanding Magnetism

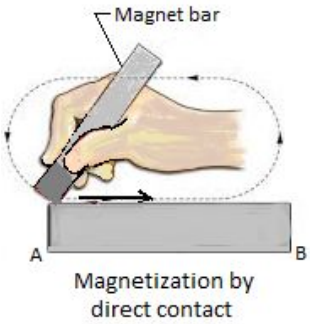
- Magnetic fields are produced by the motion of electrons and other charged particles
- Each e- has a spinning motion about an axis and an orbital motion around the nucleus → e- spin is the most important cause of magnetism bc of electron field it produces
- More unpaired e- per atom → more magnetic substance (Fe, Ni, Mn)
- Domain: group of aligned atoms forms larger magnetic field → lines up more atoms → fields act as one
  -although a domain is tiny, the magnetic fields of billions of aligned atoms give it a magnetic field that is easily detectable
  -the magnetic field of a magnet is the sum of the fields of thousands of magnetic domains
- A magnetic substance forms a magnet only if its domains are mostly aligned



- Domain theory explains how magnets work:

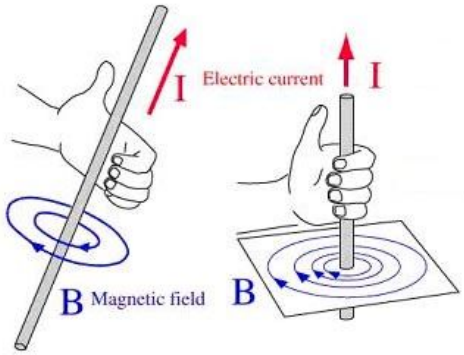
Type of substance	#unpaired e-	How affected by magnet	examples
Dia magnetic	none	weakly repelled	Pb, Cu, Hg, Au, NaCl
paramagnetic	one	weakly attracted	Al, O
ferromagnetic	more than one	strongly attracted	Fe, Co, Ni

- Magnetically soft/temporary magnet: substances that can be quickly magnetized even in a weak magnetic field (pure Fe, alloys of Fe-Ni); quickly loses magnetism when magnetic field removed
- Magnetically hard/permanent magnets: domains strongly resist changes in direction of magnetic fields; once aligned, substances retain magnetism for a very long time; made from magnetically hard materials
- Magnetizing by contact: metal substance repeatedly stroked along a magnet in the same direction, jostling the domains and aligning them with the field of the magnet; permanent or temporary
- Magnetizing by induction: temporary magnetization caused by placing an object within a magnetic field

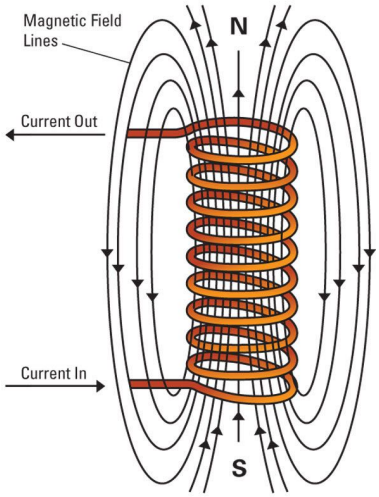


Magnetization by induction

- Magnetizing by electricity: whenever electricity flows through a wire, a magnetic field is produced around the wire
  -magnetic field produced by a wire has no poles and the flux lines flow in circles around the wire; direction of lines of flux around a current-carrying wire determined by the left-hand rule:



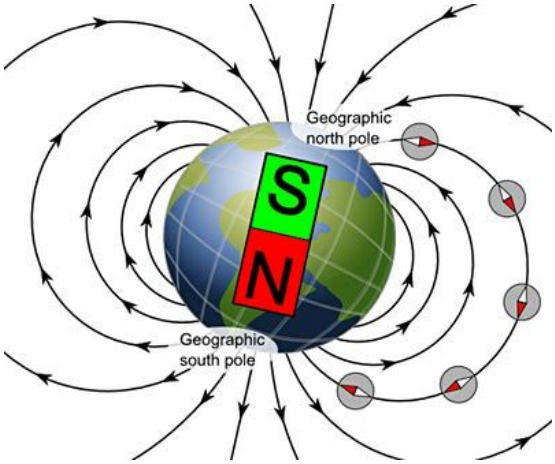
- Electromagnet: coil of wire used to produce a stronger magnetic field when electricity passes through it; adding loops strengthens each field; strength of magnet proportional to number of loops of wire in the coil:



- Demagnetization: under certain conditions, permanent magnets can lose strength or be demagnetized altogether: striking a magnet, heating to high temp
- Deflecting force: the force existing in a magnetic field that causes a moving electric charge to deviate from its original path

Earth as a Magnet

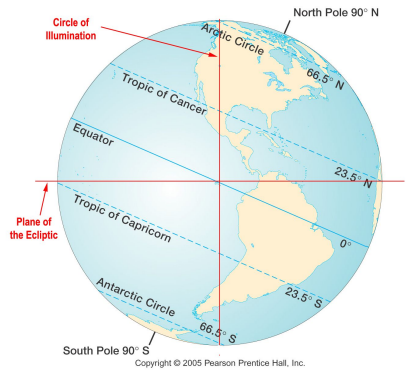
- Magnetic compass: navigational device consisting of a magnet free to swing horizontally so it always points north
  (Gilbert) compass points north because it is guided by the earth's magnetic field

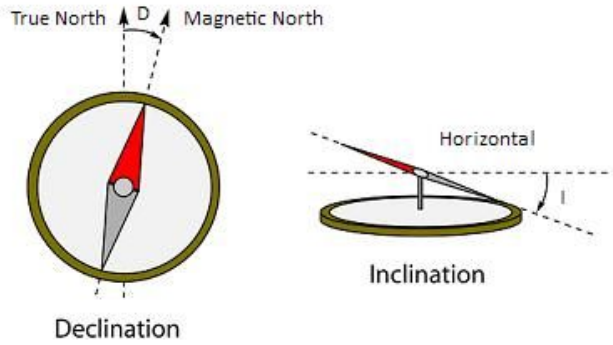


- Earth has a north pole and south pole; north pole of the compass points to the magnetically south pole of the earth; earth's north magnetic pole is actually a "south seeking" pole
- Magnetic poles do not coincide exactly with geographic poles; earth's magnetic poles are called north and south because of geographic location, not because of magnetic properties
- Angle of declination: deviation of a compass needle from pointing to true geographic north
  -isogonic lines connect points of equal declination (p. 341)

-agonic line: line connecting all points where a compass needle points true north

- Inclination: magnetic dip of north-seeking poles toward the earth in the Northern Hemisphere; angle of inclination corresponds to the angle between the earth's magnetic field and the earth's surface
  -isoclinic lines connect lines having equal inclination (p. 341)





- Magnetic equator: imaginary; circles the earth halfway between the two magnetic poles
- Magnetosphere: extent of a planet's magnetic field in space
  -outer boundary: magnetopause
  -distorted by solar wind: stream of plasma that emanates from the sun
  -Van Allen radiation belts are two belts of high-speed charged particles
- Aurora: high-speed particles from the solar wind spiral into the upper atmosphere and crash violently into molecules of air, producing display of shimmering light