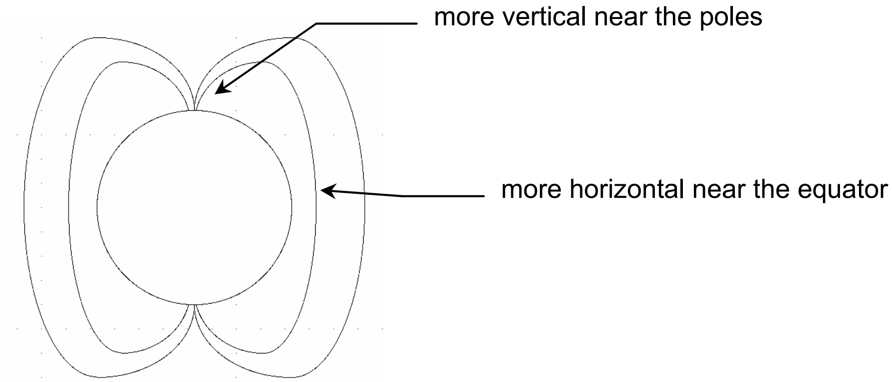
Intro: Greeks were aware of magnetic properties of certain types of iron ore before 600 BC. This type of iron ore, later called loadstone or magnite, was describes as being magnetic. The term magnetic comes from the name of the region where this type of ore was first discovered, Magnesia in Greece.

<u>Terms</u>

Inclination: This is the vertical component of the Earth's magnetic field. The Earth's magnetic field emanates from the poles. Therefore, closest to the poles, the magnetic field lines become more vertical. At the equator the magnetic field lines are most horizontal. From the measurement of inclination, one can determine how northerly or southerly his/her position is.



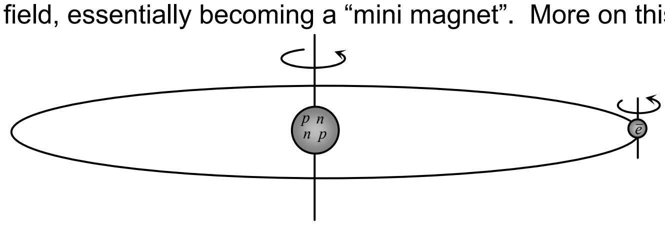
Declination: This is the offset of magnetic north from true north. Magnetic N shifts about the Earth's axis with a period of approximately 1000 years.

Domain Theory of Magnetism

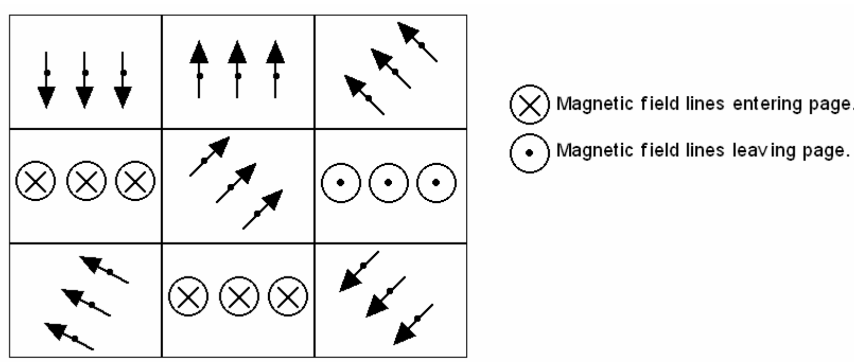
The ability for any material to exhibit magnetic properties is related to the following quantum mechanical phenomenon.

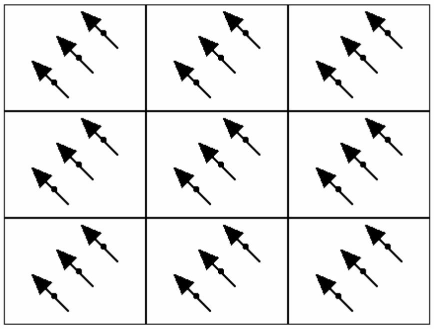
1. The spin of the electron
2. The spin of the protons in the nucleus
3. The orbit of the electron.

concept: The movement of any electric charge produces a magnetic field. Therefore, every atom will produce a magnetic field, essentially becoming a "mini magnet". More on this later.



The magnetic field produced by each atom will cause adjacent atoms to align with each other. These localized regions of magnetically aligned atoms are called **domains**. There are millions of domains in any given material, all with randomly oriented magnetic poles. The random nature of their magnetic field lines results in a net cancellation of all these magnetic fields.





In certain materials, such as iron and cobalt, these domains can be induced to become aligned. Once aligned, the material will have a net magnetic field with a distinct north and south pole.

Demagnetization: The process with which domains become randomly aligned again. Causes of this are exposure to heat or physical impact.

Soft Ferromagnetic Materials: These are materials that can become instantly magnetized when exposed to an inducing magnetic field but will lose their magnetic properties immediately after the inducing field is removed.

Hard Ferromagnetic Material: These are materials that can become magnetized when exposed to an inducing magnetic field and will retain their magnetic properties after the inducing field is removed.

Reversing Magnetization: The process with which an oppositely polarized magnetic field can reverse the magnetic polarity in permanent magnets.

Magnetic Saturation: Occurs when virtually all domains in a magnetic material are aligned, at which point the material cannot be magnetized further.

Magnetic permeability (μ): The ease with which a magnetic field can be formed in or pass through a substance.

Ferromagnetic such as iron, cobalt and nickel have high magnetic permeability

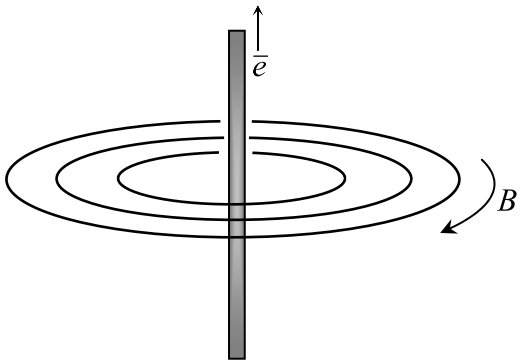
Paramagnetic materials such as aluminium and oxygen do not easily pass magnetic fields but do respond slightly better than a vacuum ($\mu = 1$)

Diamagnetic materials such as copper and water are material that are less permeable that a vacuum. These materials are used as shielding in electro-magnetically sensitive electronics.

$$\mu = \frac{\text{magetic field strength in a material}}{\text{magnetic field strength in a vacuum}}$$

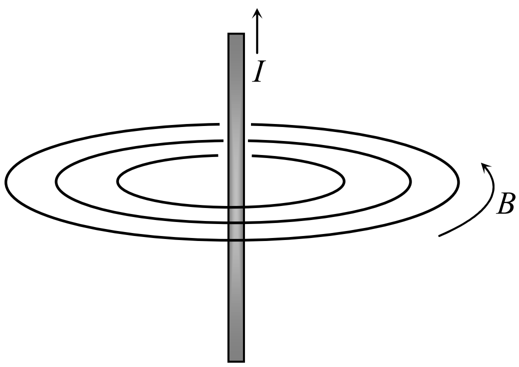
Moving Charges and Magnetic Fields: Any moving charge will induce a magnetic field at right angles to the motion of the charges. There are two rules depending on what type of charge flow is assumed.

Left Hand Rule: assumes a flow of negative charge (electrons)

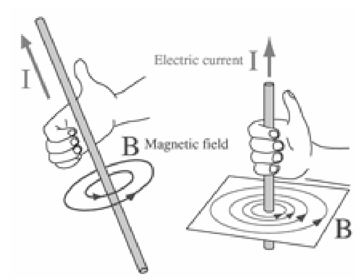


- point thumb of left hand in direction of electron flow
- fingers indicate direction of magnetic field

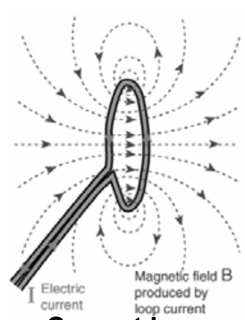
Right Hand Rule: assumes a flow of positive charge or current (I)



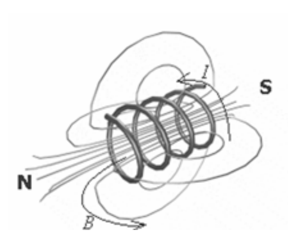
- point thumb of right hand in direction of current flow
- fingers indicate direction of magnetic fields



Magnetic Fields and The Current Loop: Any coil of wire will produce a magnetic field as illustrated below. A series of coil will produce a uniform magnetic field within the coil itself. The Left Hand and Right Hand rules apply with exception that the fingers will indicate the flow of negative or positive charge respectively, and the thumb will indicate the direction of the magnetic field (B).



Current Loop



Multi-turn Coil

Note: a multi-turn coil with an air core is called a solenoid. If the core is replace with iron or some other ferromagnetic substance it is no longer called a solenoid.

Units for magnetic field strength: Magnetic field strength is measured in Teslas where $1T = 1N / A \cdot m$ where N is Newtons, A is Amperes, m is meters. The Tesla is defined as 1A of current passing through 1 meter of a conductor experiencing a force, perpendicularly across the magnetic field, of 1N.

Factors that affect magnetic field strength in coils:

Amount of current: The more current that flows through a coil, the greater the magnetic field produced

$$B_2 = B_1\left(\frac{I_2}{I_1}\right)$$

Number of loops in a coil: Since every loop produces its own magnetic field. Every additional loop will add to the field strength. The more loops, the stronger the magnetic field

$$B_2 = B_1\left(\frac{n_2}{n_1}\right)$$

Cross-sectional area or the core: The ferromagnetic core acts as a focusing lens for magnetic fields. Decreasing the cross sectional area of the core within the coil acts to focus the existing magnetic field lines within the core resulting in a strong magnetic field. It should be noted that decreasing the diameter of the core does not produce more magnetic field lines. B is inversely proportional to cross-sectional area.

$$B_2 = B_1\left(\frac{A_1}{A_2}\right)$$

Type of core material: The type of core material will determine the field strength of the magnetic field. A paramagnetic core material will add no additional field strength where as a ferromagnetic core can increase the field strength by a thousand times. These ferromagnetic materials become magnetized in the process, which causes the increase in magnetism.

The motor principle: As discussed earlier, when a current flows through a conductor, a magnetic field is produced. If the conductor is placed in an external magnetic field that is perpendicular to the length of the wire, a force is produced in at right angles to both the flow of charge and the direction of the external magnetic field.

I.e. If you are working with negative charge flow, the left hand rule applies, such that if your thumb points in the direction of the flow of negative charge, your fingers should point in the direction of the external magnetic field. The force will be in the direction in which your palm faces.

If you are working with positive charge flow, the right hand rule applies, such that if your thumb points in the direction of the flow of positive charge (current), your fingers should point in the direction of the external magnetic field. The force will be in the direction in which your palm faces.