Magnetic Definitions

- **A/m** – Ampere turns per meter = The MKS unit of magnetic field strength (1 A/m = 4π/1000 Oersteds ≈ 0.01257 Oersteds)
- **Air Gap** - A nonmagnetic discontinuity in a magnetic circuit.
- **Anisotropic** – Not isotropic. Anisotropic materials have a grain orientation aligned in the preferred direction of magnetization. Most magnets are anisotropic and have higher induction than isotropic materials
- **BH Curve** – The plot of *B* (Induction) vs. *H* (applied magnetic field) for a magnetic material
- **cgs** – A system of units utilizing centimeters, grams, seconds, Gauss, Oersteds, and Maxwells.
- **Coercivity** - Coercive force - resistance to demagnetization; $H_{C,}$ Hcb, Hci, or Hcj
- **Curie Temperature** – The temperature at which a magnet becomes nonmagnetic
- **Demagnetization curve** – The portion of the hysteresis loop that lies between the residual induction point (B @ H=0) to the point where B = 0. (All coordinates of the demagnetization curve have a negative H.) The second (or fourth) quadrant of a major hysteresis loop.
- **Eddy Current** – The circular electrical current produced when a magnetic field changes in an electrical conductor
- **Ferromagnetic** – A class of materials with permeabilities significantly greater than one and that exhibit hysteresis properties. Ferromagnetic materials contain Iron, Cobalt, and/or Nickel
- **Flux** (ϕ) -The product of flux density and magnet area (or the integral of flux density over a magnet's pole-face area). That entity which flows from one pole to the other in a magnetic circuit. The flow of flux in a

magnetic circuit is analogous to the current flow in an electrical circuit. Flux is measured in Maxwells or Webers.
    - Lines of flux are continuous
    - Lines of flux never cross
    - Lines of flux take the path of least resistance
- **Flux density** - Induction = *B* – The Concentration of flux over a given area. Flux density is measured in Gauss or Tesla.
- **Fluxmeter** – Integrating voltmeter => Use in conjunction with a coil to measure flux
- **Gauss (G or Gs)** – The unit of flux density in the cgs system 1 Gauss = 1 Maxwell/cm^2 (1 Gauss = 10^{-4} Tesla)
- **Gaussmeter** – Device used in conjunction with a hall probe to measure flux density
- **Hard Magnetic Material** – Permanent Magnet - Magnetic material with substantial coercivity; generally > 120 Oe.
- **Helmholtz Coils** – Two identical coils of wire (wound in series and separated by one coil radius) which can be used to measure a magnetic field when attached to a fluxmeter, or to create, a magnetic field when attached to a current supply
- **Hysteresis Loop** – Full four-quadrant graph characterizing the relationship of the induction of a magnetic material to an applied magnetic field
- **Hysteresisgraph** - Permeameter - Curve Tracer - Applies a magnetic field to a magnetic material and plots the induction versus that varying field
- **Induction** - Flux density = *B* - Concentration of flux over a given area measured in Gauss or Tesla
- **Intrinsic Coercivity** - Total resistance to demagnetization (H_{ci} or Hcj) = the amount of magnetic force required to completely demagnetize a magnetic material. After applying an H_{cj} amount of demagnetizing field, $B_i = 0$.

- **Intrinsic Curve** - The plot of the intrinsic induction vs. applied magnetic field $B - H$ vs. H or Bi vs. H curve (as opposed to the normal curve)
- **Irrecoverable losses** – Those magnet losses that cannot be recovered by any means.
- **Isotropic** – Isotropic materials are identical in all directions (Demagnetization curves run on isotropic materials are identical regardless of the direction in which the material is magnetized)
- **Keeper** – A piece of high permeability material placed on, or between, the magnet pole face(s) that is used to decrease reluctance and thereby decreasing the magnet's susceptibility to demagnetization.
- **kJ/m^3** - Units of energy in MKS system (1 kJ/m^3 = 4π/100 MGOe ≈ 0.1257 MGOe)
- **Knee of the Curve** – That portion of the demagnetization curve where the shape of the line turns from near-straight to curved
- **Leakage** - Leakage Flux (σ) - The lines of flux that do not travel through the area where you want to use them (useless flux)
- **Lines** - Lines of Flux. 1 Line of flux = 1 Maxwell
- **Magnetic Circuit** – A closed path of magnetic flux that contains flux at every point
- **Maxwell** – cgs unit of flux (1 Maxwell = 10^{-8} Webers)
- **Meter Kilogram Second (MKS)** – The MKS system of units expresses terms in fundamental units of meters, kilograms, seconds, Tesla, Ampere turns/meter, or Webers.
- **MGO** - MGOe - Million Gauss Oersteds - The cgs unit of magnetic energy product (1 MGO = (100/4π) kJ/m^3 ≈ 7.96 kJ/m^3)
- **Neutral zone** – that area of a permanent magnet where the polarity changes and little or no flux is produced.
- **Normal Coercivity** - (Hc or Hcb); That exact amount of demagnetizing field required to negate the magnetic field produced by a permanent magnet.

- **Normal Curve** – The *B* vs. *H* curve of a magnetic material (as opposed to the *B* – *H* vs. *H intrinsic* curve)
- **North Pole -** The magnet pole attracted to the earth's North. (The earth's geographic North Pole is a magnetic South Pole.)
- **Oersted** – The cgs unit of magnetic field strength (1 Oersted ≈ 79.6 A/m)
- **Open Circuit** – A magnet is said to be operating open-circuit when it is separated from other magnetic materials
- **Operating Point** – That point where the load line crosses the normal curve (B_d, H_d)
- **Permeance** - Permeance Coefficient - Load Line = Pc = B_d/H_d = [(Area of the gap / Length of the gap) *(Length of the magnet / Area of the magnet) * (Leakage/Reluctance)]. The slope of a line drawn on the demagnetization curve from the coordinate 0,0 to the operating point B_d/H_d (It is usually a negative number, but the sign is typically omitted.) The MKS system of units is Henrys, the cgs is Maxwells/gilbert.
- **Permeance Coefficient** - Load Line - The slope of a line drawn from the coordinate 0,0 to the point B_d/H_d (It is usually a negative number, but the sign is often omitted)
- **Permeability** – (μ) The ratio of the flux density in a material to the magnetic force producing it. (Permeabilities are typically specific to the magnitude of the applied field.) Its MKS system of units is Henrys/meter and it is unitless in the cgs system.
- **Recoverable losses** – those magnet loses that can be recovered by remagnetization.
- **Initial Permeability** - (μ_0) The ratio of change in flux density as a function of incremental change in applied field very near H=0.
- **Recoil Permeability** - (μ_{re}) is the average slope of the recoil hysteresis loop. (This recoil hysteresis loop is also known as a minor loop.)
- **Relative Permeability -** (μ_r) The ratio of the permeability of a substance to the permeability of a vacuum at the same applied field level.

- **Residual Induction -** (Br) After magnetization to saturation, Br is the magnetic induction corresponding to the point where zero magnetizing/demagnetizing field is applied.
- **Pole Piece -** A piece of soft magnetic material added to a permanent magnet used to redirect the flux.
- **Reluctance** – (R_f) A magnetic circuit's resistance to the flow of flux; ~~(~~the reciprocal of permeance. The reluctance of magnetic flux in a magnetic circuit is analogous to the resistance to current flow in an electrical circuit.
  It's MKS units are 1/Henry, the cgs units are gilberts/Maxwell.
- **Reversible temperature coefficient** – The changes in a magnet's unit properties (typically Br or Hcj) due to a change in temperature; typically expressed in units of %/°C.
- **Saturation** – (1) When a soft magnetic material reaches saturation, it cannot carry any more flux. After saturation, a material reacts to additional flux as if that material has a permeability of 1.0 (the same as air) (2) When we say we magnetize a permanent magnet to saturation, we mean that magnetizing with any higher field will not result in additional B.
- **Search Coil -** is a coiled electrical conductor, of known turns and usually of known area, which is used with a Fluxmeter to measure the change of flux from one position to another. Most often the coil tightly encircles a permanent magnet at its transition zone and that magnet's total flux is measured, by the Fluxmeter, when the coil is slipped off.
- **Soft magnetic material** – Magnetic material with low resistance to demagnetization
- **South Pole -** The magnet pole attracted to the bottom of the earth and to a magnet's North pole.
- **Structural loses -** A type of irrecoverable loss that happens when the magnet's fundamental physical properties are changed.
- **Temperature coefficient -** The change of a property as a function of change in temperature. In the magnetic context; that amount of change a magnet's induction or coercivity experiences as the magnet's

temperature changes (usually expressed in units of: (%/^{o}C) {i.e. the temperature coefficient of residual induction = $\Delta B_r/(B_r * \Delta T)$ and the temperature coefficient of coercivity = $\Delta H_{ci}/(H_{ci} * \Delta T)$}

- **Tesla** - The MKS unit of flux density (1 Tesla = 10^4 Gauss)
- **Transition zone** - that area of a permanent magnet where the polarity changes
- **Weber -** The MKS unit of flux (1 Weber = 10^8 Maxwells)

References:

1. *Permanent Magnets and Their Applications*, Rollin J. Parker and Robert J. Studders, John Wiley & Sons, New York, 1962
2. *Permanent Magnet Design and Application Handbook,* Lester R. Moskowitz, Keieger Publishing Company, Malabar Florida, 1995
3. *Permanent Magnet Guidelines,* MMPA PMG-88, various authors, Publication of MMPA, 8 South Michigan Avenue, Suite 1000, Chicago, IL, 1988

Symbols

- **α** = Reversible temperature coefficient of Br (αB_r); also sometimes used with Hcj
- **A/m** = Ampere turns per meter
- $\mathbf{A_m}$ = Area of magnet
- $\mathbf{A_g}$ = Area of gap
- **B** = Induction = flux density
- **β** = reversible temperature coefficient of Hcj
- $\mathbf{B_d}$ = Induction at the operating permeance; sometimes induction at max energy
- $\mathbf{B_g}$ = Magnetic induction in the air gap
- $\mathbf{B_i}$ = J = Intrinsic Induction at the operating permeance
- $\mathbf{B_m}$ = Recoil Induction
- $\mathbf{B_r}$ = Residual Induction
- $\mathbf{B_{sat}}$ = Saturation Induction
- **B/H** = Pc = Load line (slope of) = Permeance
- $\mathbf{(BH)_{max}}$ = Maximum energy product
- **eV** = Electron volt
- **F** = Leakage factor
- **F** = Magnetomotive force
- **ϕ** = Flux
- **G** = Gauss
- **Gb** = Gilberts
- **H** = Magnetic Field (or Magnetic Force)
- **H** = Henries
- $\mathbf{H_{cb}}$ = H_c = Normal Coercive Force
- $\mathbf{H_{cj}}$ = H_{ci} = Intrinsic Coercive Force
- $\mathbf{H_d}$ = H at the operating permeance; sometimes H at max energy
- $\mathbf{H_k}$ = The H coordinate of the point where $B_i = 0.9*B_r$
- $\mathbf{H_m}$ = The value of H corresponding to the recoil induction; B_m
- **J** = B_i = Intrinsic Induction
- **J** = Joules
- $\mathbf{J/m^3}$ = Joules per cubic meter
- $\mathbf{L_g}$ = Length of gap
- $\mathbf{L_m}$ = Length of magnet
- **M** = Magnetization
- **←M→** = Direction of Magnetization
- **Mx** = Maxwells
- **MGO** = MGOe = Million Gauss Oersteds
- **N** = North Pole
- **Oe** = Oersteds
- **ρ** = Density
- $\mathbf{P_c}$ = B/H = Permeance coefficient = Load line
- **R** = Reluctance
- **S** = South Pole
- **T** = Tesla
- $\mathbf{T_c}$ = Curie temperature
- **μ** = Permeability
- $\mathbf{\mu_0}$ = Permeability of vacuum
- $\mathbf{\mu_r}$ = Relative permeability
- $\mathbf{\mu_{re}}$ = Recoil permeability
- $\mathbf{V_g}$ = Volume of the air gap
- $\mathbf{V_m}$ = Volume of the magnet
- **Vs** = Volt seconds
- **Wb** = Webers