GAUSS'S LAW FOR MAGNETIC FIELDS

$\overline{B}$ FIELD (MAGNETIC FLUX DENSITY, OR MAGNETIC INDUCTION)

① DEFINED AS THE MAGNETIC FORCE EXPERIENCED BY A MOVING CHARGED PARTICLE.

FROM THE LORENTZ EQUATION

$$\overline{F} = q\left[\overline{E} + (\overline{v} \times \overline{B})\right] \quad \leftarrow \text{LORENTZ EQUATION}$$

AND

$$\overline{F}_B = q\,(\overline{v} \times \overline{B})$$

EXAMPLE: RAILGUN

WHERE $\overline{F}_B$ IS THE MAGNETIC FORCE, q IS THE PARTICLE CHARGE, $\overline{v}$ IS THE PARTICLE VELOCITY WITH RESPECT TO $\overline{B}$, AND $\overline{B}$ IS THE MAGNETIC FIELD.

② $\overline{B}$ HAS UNITS OF $\dfrac{N}{C\,(m/s)} = \dfrac{Vs}{m^2} = \dfrac{N}{Am} = \dfrac{Kg}{Cs} = T$

③ COMPARING $\overline{F}_E = q\overline{E}$ AND $\overline{F}_B = q\,(\overline{v} \times \overline{B})$,

A) $\overline{F}_E$ IS PARALLEL TO THE ~~FORCE~~ FIELD, $\overline{F}_B$ IS PERPENDICULAR TO THE $\overline{B}$ FIELD.

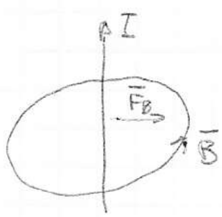
B) WITH $\overline{B}$, WE NEED TO CONSIDER THE SPEED AND DIRECTION OF THE PARTICLE.

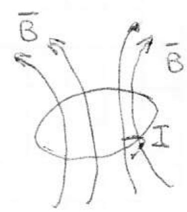
C) THE COMPONENT OF $\overline{F}_B$ IN THE DIRECTION OF DISPLACEMENT OF THE PARTICLE IS ZERO. THEN, A $\overline{B}$ FIELD CANNOT DO WORK ON A CHARGED PARTICLE.

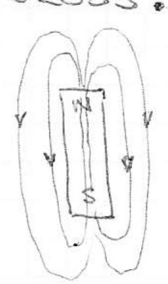
D) ELECTROSTATIC FIELDS ARE PRODUCED BY ELECTRIC CHARGES, BUT MAGNETOSTATIC FIELDS ARE PRODUCED BY ELECTRIC CURRENTS

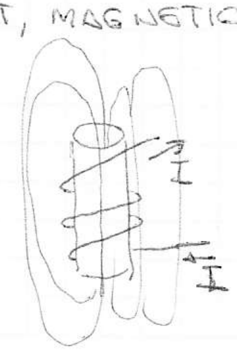
④ MAGNETIC FIELDS MAY BE REPRESENTED BY LINES.

⑤ THE NET MAGNETIC FIELD AT A GIVEN POINT IS THE VECTOR SUM OF ALL MAGNETIC FIELDS PRESENT AT THAT POINT. BECAUSE OF THAT, MAGNETIC FIELD LINES NEVER CROSS.



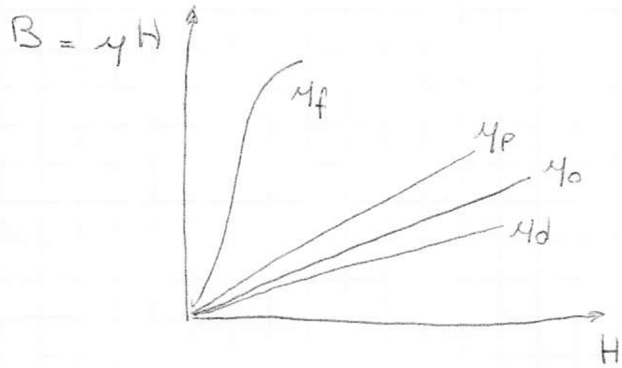






MAGNETIC PERMEABILITY (μ_0)

MEASURE THE ABILITY OF A MATERIAL TO SUPPORT THE FORMATION OF A MAGNETIC FIELD WITHIN ITSELF, THE DEGREE OF MAGNETIZATION INSIDE THE MATERIAL IN RESPONSE TO AN APPLIED B FIELD.



~~μ_0 IS MEASURED IN~~

μ_0 VALUE IS $4\pi \times 10^{-7}$ $\left[\frac{H}{m} = \frac{N}{A^2}\right]$

MATERIALS CAN BE CLASSIFIED DEPENDING ON THEIR PERMEABILITY IN:

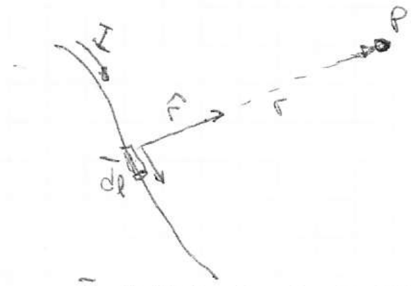
1. FERROMAGNETIC: μ_f MATERIAL BECOMES PERMANENTLY MAGNETIZED BY EXTERNAL FIELD ~~(UNTIL~~.
2. PARAMAGNETIC: $\mu_p > 1$. WEAK MAGNETIZATION IN MATERIAL IN THE PRESENCE OF EXTERNAL MAGNETIC FIELD.
3. DIAMAGNETIC: $\mu_d < 1$. WEAK EFFECT, BUT STRONG IN SUPERCONDUCTORS. MATERIAL CREATES A INTERNAL MAGNETIC FIELD OPPOSING THE EXTERNAL FIELD.

μ VARIES WITH POSITION, FREQUENCY, HUMIDITY, TEMPERATURE, ETC.

BECAUSE OF THIS, COMPLEX PERMITTIVITY IS USED SOMETIMES AT HIGH-FREQUENCY FREQ. DOMAIN TREATMENTS TO ACCOUNT FOR LAG (AS PHASE), AND SOME OTHER TIMES μ IS MODELED AS A RANK 2 TENSOR TO ACCOUNT FOR ANISOTROPIC MEDIUM.

BIOT - SAVART LAW

$$d\bar{B} = \frac{\mu_0}{4\pi} \frac{I\, d\bar{l} \times \hat{r}}{r^2}$$



WHERE μ_0 IS THE MAGNETIC PERMEABILITY OF FREE SPACE, I IS THE CURRENT THROUGH THE SMALL ELEMENT, $d\bar{l}$ IS THE ~~DIF~~ A VECTOR WITH THE LENGHT OF A CURRENT ELEMENT IN THE DIRECTION OF THE CURRENT, $\hat{r}$ POINTS TO THE POINT IN WHICH $\bar{B}$ IS TO BE DETERMINED, AND r IS THE DISTANCE BETWEEN $d\bar{l}$ AND P.

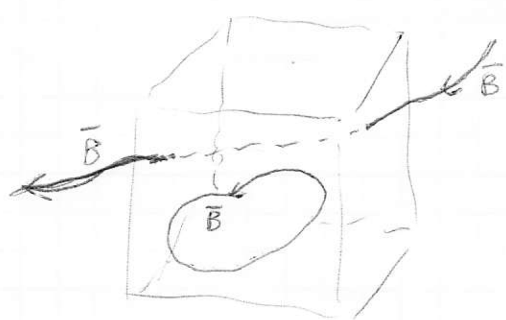
$\bar{B}$ FIELD AT P IS DETERMINED BY ADDING ALL THE DIFFERENTIAL CONTRIBUTIONS.

GAUSS'S LAW FOR MAGNETIC FIELDS (INTEGRAL)

$$\boxed{\oint_S \bar{B} \cdot \hat{n}\, ds = 0}$$

THE TOTAL MAGNETIC FLUX PASSING THROUGH ANY CLOSED SURFACE IS ZERO.

THIS IS DUE TO THE FACT THAT FOR EVERY LINE ENTERING THE CLOSED SURFACE THERE IS A FIELD LINE EXITING THE SURFACE (LINES FORM CLOSED LOOPS).



Φ_B = MAGNETIC FLUX THROUGH A SURFACE.

Φ_B IS A SCALAR QUANTITY, MEASURED IN $Wb = T\, m^2$.

FOR AN ARBITRARY SURFACE,

$$\boxed{\Phi_B = \int_S \bar{B} \cdot \hat{n}\, ds} \; [Wb]$$