Electromagnetics Cheatsheet

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Multi-Variable Calculus

Vector Algebra

- **Thm 0:** $\vec{A} =< A_i\hat{a}_i, A_j\hat{a}_j, A_k\hat{a}_k >,\ ||\vec{A}|| = \sqrt{A_i^2 + A_j^2 + A_k^2}$
- **Thm 1:** $||c\vec{A}|| = |c|\ ||\vec{A}||$
- **Thm 2:** $\vec{a} = \frac{\vec{A}}{||\vec{A}||}$ a:a is unit vector
- **Thm 3: Dot Product** $\vec{A}\cdot\vec{B} = A_iB_i + A_jB_j + A_kB_k$
- **Thm 4: Dot Product Properties**
  $$\begin{array}{l|l} \vec{a}\cdot\vec{b} = (\vec{b}\cdot\vec{a}) & (c\vec{a})\cdot\vec{b} = \vec{a}\cdot(c\vec{b}) = c(\vec{a}\cdot\vec{b}) \\ \vec{a}\cdot(\vec{b}+\vec{c}) = \vec{a}\cdot\vec{b} + \vec{a}\cdot\vec{c} & 0\cdot\vec{a} = 0 \\ (\vec{a}+\vec{b})\cdot\vec{c} = \vec{a}\cdot\vec{b} + \vec{a}\cdot\vec{c} & \vec{a}\cdot\vec{a} = ||\vec{A}||^2 \end{array}$$
- **Thm 5: Angle** $\vec{a}\cdot\vec{b} = ||\vec{a}||\ ||\vec{b}||\ cos\ \theta,\ \ \theta : 0 < \theta < \pi$
- **Thm 6: Orthogonality** $\vec{a}\perp\vec{b} \iff \vec{a}\cdot\vec{b} = 0$
- **Thm 7: Component (Scalar)** $\text{comp}_{\vec{a}}\vec{b} = ||\vec{b}||\ cos\ \theta = \frac{\vec{a}\cdot\vec{b}}{||\vec{a}||}$
- **Thm 8: Projection (Vector)** $\text{proj}_{\vec{a}}\vec{b} = \text{comp}_{\vec{a}}\vec{b}\cdot\frac{\vec{a}}{||\vec{a}||} = \frac{\vec{a}\cdot\vec{b}}{\vec{a}\cdot\vec{a}}\vec{a}$
- **Thm 9: $\perp$ Projection (Vector)** $\text{oproj}_{\vec{a}}\vec{b} = \vec{b} - \text{proj}_{\vec{a}}\vec{b}$
- **Thm 10: Cross Product** $\vec{A}\times\vec{B} = \begin{vmatrix} i & j & k \\ A_i & A_j & A_k \\ B_i & B_j & B_k \end{vmatrix}$
- **Thm 11: Cross Product Properties**
  $$\begin{array}{l|l} \vec{a}\times\vec{b} = -(\vec{b}\times\vec{a}) & (c\vec{a})\times\vec{b} = \vec{a}\times(c\vec{b}) = c(\vec{a}\times\vec{b}) \\ \vec{a}\times(\vec{b}+\vec{c}) = \vec{a}\times\vec{b} + \vec{a}\times\vec{c} & 0\times\vec{a} = \vec{0} \\ (\vec{a}+\vec{b})\times\vec{c} = \vec{a}\times\vec{c} + \vec{b}\times\vec{c} & \vec{a}\times\vec{a} = 0 \end{array}$$
- **Thm 11: Angle** $\vec{a}\cdot\vec{b} = ||\vec{a}||\ ||\vec{b}||\ sin\ \theta,\ \ \theta : 0 < \theta < \pi$
- **Thm 12: Parallelity** $\vec{a} \parallel \vec{b} \iff \vec{a}\times\vec{b} = 0$
- **Thm 13:** $\vec{c} = \vec{a}\times\vec{b} : \vec{c}\perp\vec{a},\vec{b}$
- **Thm 14: Area of parallelogram** $||\vec{a}\times\vec{b}||$
- **Thm 15: Area of triangle** $\frac{1}{2}||\vec{a}\times\vec{b}||$
- **Thm 16: Triple Product (Scalar)**
  $$\vec{A}\times\vec{B}\cdot\vec{C} = \vec{A}\cdot\vec{B}\times\vec{C}\begin{vmatrix} A_i & A_j & A_k \\ B_i & B_j & B_k \\ C_i & C_j & C_k \end{vmatrix}$$

Vector Geometry

Coordinates

- Cartesian:
  $$\vec{A} =< A_x\hat{a}_x, A_y\hat{a}_y, A_z\hat{a}_z >$$
  $$-\infty < x, y, z < \infty$$
- Cylindrical:
  $$\vec{A} =< A_\rho\hat{a}_\rho, A_\phi\hat{a}_\phi, A_z\hat{a}_z >$$
  $$0 \le \rho < \infty, 0 \le \phi < 2\pi, -\infty < z < \infty$$
- Spherical:
  $$\vec{A} =< A_r\hat{a}_r, A_\theta\hat{a}_\theta, A_\phi\hat{a}_\phi >$$
  $$0 \le r < \infty, 0 \le \theta < \pi, 0 \le \phi < 2\pi$$

Transformations

Cylindrical $\iff$ Spherical

$$\begin{bmatrix} A_r \\ A_\theta \\ A_\phi \end{bmatrix} = \begin{bmatrix} \sin(\theta) & 0 & \cos(\theta) \\ \cos(\theta) & 0 & -\sin(\theta) \\ 0 & 1 & 0 \end{bmatrix}\begin{bmatrix} A_\rho \\ A_\phi \\ A_z \end{bmatrix}$$

$$\begin{bmatrix} A_\rho \\ A_\phi \\ A_z \end{bmatrix} = \begin{bmatrix} \sin(\theta) & \cos(\theta) & 0 \\ 0 & 0 & 1 \\ \cos(\theta) & -\sin(\theta) & 0 \end{bmatrix}\begin{bmatrix} A_r \\ A_\theta \\ A_\phi \end{bmatrix}$$

$$r = \sqrt{\rho^2 + z^2},\ \rho = rsin(\theta)$$
$$\theta = tan^{-1}(\tfrac{\rho}{z}),\ z = rcos(\theta)$$
$$\phi = \phi$$

Cartesian $\iff$ Cylindrical

$$\begin{bmatrix} A_\rho \\ A_\phi \\ A_z \end{bmatrix} = \begin{bmatrix} \cos(\phi) & \sin(\phi) & 0 \\ -\sin(\phi) & \cos(\phi) & 0 \\ 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} A_x \\ A_y \\ A_z \end{bmatrix}$$

$$\begin{bmatrix} A_x \\ A_y \\ A_z \end{bmatrix} = \begin{bmatrix} \cos(\phi) & -\sin(\phi) & 0 \\ \sin(\phi) & \cos(\phi) & 0 \\ 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} A_\rho \\ A_\phi \\ A_z \end{bmatrix}$$

$$\rho = \sqrt{x^2 + y^2},\ x = \rho cos(\theta)$$
$$\phi = tan^{-1}(\tfrac{y}{x}),\ y = \rho sin(\theta)$$
$$z = z$$

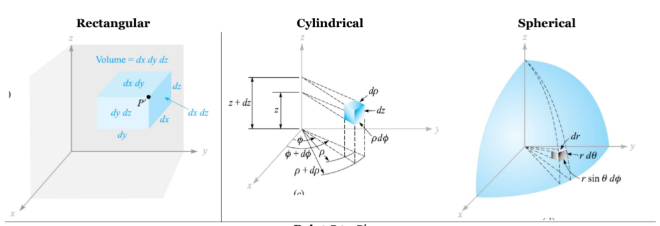
Cartesian $\iff$ Spherical

$$\begin{bmatrix} A_r \\ A_\theta \\ A_\phi \end{bmatrix} = \begin{bmatrix} \sin(\theta)cos(\phi) & \sin(\theta)sin(\phi) & \cos(\theta) \\ \cos(\theta)cos(\phi) & \cos(\theta)sin(\phi) & -\sin(\theta) \\ -\sin(\phi) & \cos(\phi) & 0 \end{bmatrix}\begin{bmatrix} A_x \\ A_y \\ A_z \end{bmatrix}$$

$$\begin{bmatrix} A_x \\ A_y \\ A_z \end{bmatrix} = \begin{bmatrix} \sin(\theta)cos(\phi) & \cos(\theta)cos(\phi) & -\sin(\phi) \\ \sin(\theta)sin(\phi) & \cos(\theta)sin(\phi) & \cos(\phi) \\ \cos(\theta) & -\sin(\theta) & 0 \end{bmatrix}\begin{bmatrix} A_r \\ A_\theta \\ A_\phi \end{bmatrix}$$

$$r = \sqrt{x^2 + y^2 + z^2},\ x = rsin(\theta)cos(\phi)$$
$$\theta = cos^{-1}(\frac{z}{\sqrt{x^2+y^2+z^2}}),\ y = rsin(\theta)sin(\phi)$$
$$z = rcos(\theta),\ \phi = tan^{-1}\tfrac{y}{x}$$

Overview



Point P to P'		
$P(x,y,z) \to P(x+dx, y+dy, z+dz)$	$P(\rho,\phi,z) \to P(\rho+d\rho, \phi+d\phi, z+dz)$	$P(r,\theta,\phi) \to P(r+dr, \theta+d\theta, \phi+d\phi)$
Differential Line		
In x direction: $\mathbf{dl_x} = dx\,\mathbf{a_x}$	In ρ direction: $\mathbf{dl_\rho} = d\rho\,\mathbf{a_\rho}$	In r direction: $\mathbf{dl_r} = dr\,\mathbf{a_r}$
In y direction: $\mathbf{dl_y} = dy\,\mathbf{a_y}$	In ϕ direction: $\mathbf{dl_\phi} = \rho\,d\phi\,\mathbf{a_\phi}$	In θ direction: $\mathbf{dl_\theta} = r\,d\theta\,\mathbf{a_\theta}$
In z direction: $\mathbf{dl_z} = dz\,\boldsymbol{a_z}$	In z direction: $\mathbf{dl_z} = dz\,\boldsymbol{a_z}$	In ϕ direction: $\mathbf{dl_\phi} = r\sin\theta\,d\phi\,\boldsymbol{a_\phi}$
$\mathbf{dl} = dx\,\mathbf{a_x} + dy\,\mathbf{a_y} + d_z\,\mathbf{a_z}$	$\mathbf{dl} = d\rho\,\mathbf{a_\rho} + \rho\,d\phi\,\mathbf{a_\phi} + dz\,\boldsymbol{a_z}$	$\mathbf{dl} = dr\,\mathbf{a_r} + r\,d\theta\,\mathbf{a_\theta} + r\sin\theta\,d\phi\,\boldsymbol{a_\phi}$
Differential Area		
Constant x: $\mathbf{dS_x} = dy\,dz\,\mathbf{a_x}$	Constant ρ: $\mathbf{dS_\rho} = \rho\,d\phi\,dz\,\mathbf{a_\rho}$	Constant r: $\mathbf{dS_r} = r^2\sin\theta\,d\theta\,d\phi\,\mathbf{a_r}$
Constant y: $\mathbf{dS_y} = dx\,dz\,\mathbf{a_y}$	Constant ϕ: $\mathbf{dS_\phi} = d\rho\,dz\,\mathbf{a_\phi}$	Constant θ: $\mathbf{dS_\theta} = r\sin\theta\,dr\,d\phi\,\mathbf{a_\theta}$
Constant z: $\mathbf{dS_z} = dx\,dy\,\mathbf{a_z}$	Constant z: $\mathbf{dS_z} = \rho\,d\phi\,d\rho\,\mathbf{a_z}$	Constant ϕ: $\mathbf{dS_\phi} = r\,dr\,d\theta\,\mathbf{a_\phi}$
Differential Volume		
$dv = dx\,dy\,dz$	$dv = \rho\,d\rho\,d\phi\,dz$	$dv = r^2\sin\theta\ dr\,d\theta\,d\phi$

Vector Calculus

- **Thm 0: Green**
  $$\oint_{\partial D}\vec{F}\cdot d\vec{r} = \iint_D\left(\frac{\partial Q}{\partial x} - \frac{\partial P}{\partial y}\right)dx\,dy$$
- **Thm 1: Gauss**
  $$\iiint_V \nabla\cdot\vec{F}\,dV = \oint_S \vec{F}\cdot d\vec{S}$$
- **Thm 2: Stokes**
  $$\oint_C \vec{F}\cdot d\vec{r} = \iint_S(\nabla\times\vec{F})\cdot d\vec{S}$$

Nabla

Cartesian:
$$\nabla = \frac{\partial}{\partial x}\hat{x} + \frac{\partial}{\partial y}\hat{y} + \frac{\partial}{\partial z}\hat{z}$$

Cylindrical:
$$\nabla = \frac{\partial}{\partial\rho}\hat{\rho} + \frac{1}{\rho}\frac{\partial}{\partial\phi}\hat{\phi} + \frac{\partial}{\partial z}\hat{z}$$

Spherical:
$$\nabla = \frac{\partial}{\partial r}\hat{r} + \frac{1}{r}\frac{\partial}{\partial\theta}\hat{\theta} + \frac{1}{r\sin(\theta)}\frac{\partial}{\partial\phi}\hat{\phi}$$

Div

Cartesian:
$$\nabla\cdot\vec{D} = \frac{\partial D_x}{\partial x} + \frac{\partial D_y}{\partial y} + \frac{\partial D_z}{\partial z}$$

Cylindrical:
$$\nabla\cdot\vec{D} = \frac{1}{\rho}\frac{\partial\rho D_\rho}{\partial\rho} + \frac{1}{\rho}\frac{\partial D_\phi}{\partial\phi} + \frac{\partial D_z}{\partial z}$$

Spherical:
$$\nabla\cdot\vec{D} = \frac{1}{r^2}\frac{\partial r^2 D_r}{\partial r} + \frac{1}{rsin\theta}\frac{\partial sin\theta D_\theta}{\partial\theta} + \frac{1}{rsin\theta}\frac{\partial D_\phi}{\partial\phi}$$

Curl

Cartesian:
$$\nabla\times\vec{H} = \begin{vmatrix} a_x & a_y & a_z \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ H_x & H_y & H_z \end{vmatrix}$$

Cylindrical:
$$\nabla\times\vec{H} = \frac{1}{\rho}\begin{vmatrix} a_\phi & a_\phi & a_z \\ \frac{\partial}{\partial\rho} & \frac{\partial}{\partial\phi} & \frac{\partial}{\partial z} \\ H_\rho & \rho H_\phi & H_z \end{vmatrix}$$

Spherical:
$$\nabla\times\vec{H} = \frac{1}{r^2 sin\theta}\begin{vmatrix} a_r & a_\theta & a_z \\ \frac{\partial}{\partial r} & \frac{\partial}{\partial\theta} & \frac{\partial}{\partial\phi} \\ H_\rho & rH_\theta & rsin\theta H_\phi \end{vmatrix}$$

Notes

$\nabla\cdot D = 0$	$\nabla\times H = 0$
Divergent-free	Curl-free
Source-free	Irrational
Solenoid	Conservative

- Gradient is Vector indicates the encreasing direction.
- Div is Scalar indicates sources (+ve) and sinks (-ve).
- Curl is Vector indicates rotation ccw (+ve) and cw (-ve).
- Div of Curl = 0, Curl of Grad = 0, Div of Grad = Laplace.
- Closed integral doesn't depends on path in case of curl-free.

Static Electromagnetism

Maxwell Equations

	Integral Form	Point Form
Kirchhoff's Voltage Law	$\oint \vec{E} \cdot d\vec{L} = 0$	$\nabla \times \vec{E} = 0$
Ampere's Current Law	$\oint \vec{H} \cdot d\vec{L} = \int \vec{J} \cdot d\vec{S} = I_{enc}$	$\nabla \times \vec{H} = J$
Gauss's Law for E-Field	$\oint \vec{D} \cdot d\vec{S} = \int \rho dV$	$\nabla \cdot \vec{D} = \rho_v$
Gauss's Law for H-Field	$\oint \vec{B} \cdot d\vec{S} = 0$	$\nabla \cdot \vec{B} = 0$

Analogy Between Electric and Magnetic

Electric Field Intensity $\vec{E}$ $[\frac{V}{m}]$	Magnetic Field Intensity $\vec{H}$ $[\frac{A}{m}]$
Permittivity $\epsilon = \epsilon_0 \epsilon_r$ $[\frac{F}{m}]$	Permeability $\mu = \mu_0 \mu_r$ $[\frac{H}{m}]$
Coulomb's Law $dE = \frac{dQ}{4\pi\epsilon R^2}\vec{a}_r \iff E = \int \frac{dQ}{4\pi\epsilon R^2}\vec{a}_r$	Biot-Savart Law $dH = \frac{Id\vec{L} \times \vec{a}_r}{4\pi\epsilon R^2} \iff H = \int \frac{Id\vec{L} \times \vec{a}_r}{4\pi\epsilon R^2}$
Kirchhoff Voltage Law $\oint \vec{E} \cdot d\vec{L} = 0$ $\nabla \times \vec{E} = 0$	Ampere Current Law $\oint \vec{H} \cdot d\vec{L} = I_{enc}$ $\nabla \times \vec{H} = J$
Electric Flux Density $\vec{D} = \epsilon \vec{E}$ $[\frac{C}{m^2}]$	Magnetic Flux Density $\vec{B} = \mu \vec{H}$ $[\frac{\mathrm{Wb}}{m^2}]$
Electric Flux Lines $\psi = \oint \vec{D} \cdot d\vec{S}$ $[C]$	Magnetic Flux Lines $\phi = \int_S \vec{B} \cdot d\vec{S}$ [Wb]
Gauss Law for E-Field $\oint \vec{D} \cdot d\vec{S} = Q_{enc}$ $\nabla \cdot \vec{D} = \rho_v$	Gauss Law for H-Field $\oint \vec{B} \cdot d\vec{S} = 0$ $\nabla \cdot \vec{B} = 0$
Stored Electric Energy $W_E = \frac{1}{2}\int \vec{D} \cdot \vec{E}\, dv$ $\vec{D} \cdot \vec{E} = \epsilon E^2 = \frac{D^2}{\epsilon}$	Stored Magnetic Energy $W_E = \frac{1}{2}\int \vec{B} \cdot \vec{H}\, dv$ $\vec{B} \cdot \vec{H} = \mu H^2 = \frac{B^2}{\mu}$ $W_E = \int \vec{B} \cdot d\vec{H}$
Uniform E-Flux Lines $\psi = \vec{D} \cdot \vec{A} = Q_{enc}$	Uniform H-Flux Lines $\psi = \vec{B} \cdot \vec{A}$
Electric Force $F = qE$	Magnetic Force $F = q(v \times B)$

All Differential Elements

- **Electric Field**

$$dE = \begin{cases} \frac{\rho_L dl}{4\pi R^2 \epsilon}\vec{a}_r & \text{Line,} \\ \frac{\rho_S dS}{4\pi R^2 \epsilon}\vec{a}_r & \text{Surface,} \\ \frac{\rho_V dV}{4\pi R^2 \epsilon}\vec{a}_r & \text{Volume.} \end{cases}$$

- **Electric Potential**

$$dV = \begin{cases} \frac{\rho_L dl}{4\pi R \epsilon}\vec{a}_r & \text{Line,} \\ \frac{\rho_S dS}{4\pi R \epsilon}\vec{a}_r & \text{Surface,} \\ \frac{\rho_V dV}{4\pi R \epsilon}\vec{a}_r & \text{Volume.} \end{cases}$$

- **Magnetic Field**

$$dH = \frac{Id\vec{L} \times \vec{a}_r}{4\pi R^2}$$

Analogy Between Capacitance and Inductor

Capacitance	Inductor
Capacitance $C = \frac{Q}{V} = \frac{\epsilon A}{l}$	Inductance $L = \frac{N\Phi}{I} = \frac{NBA}{I}$
Relative Permittivity $\epsilon_r = \frac{C}{C_o} = \frac{Q}{Q_o}$	Relative Permeability $\mu_r = \frac{L}{L_o} = \frac{B}{B_o}$
Electric Dipole Moment $\vec{p} = Q\vec{x}$	Magnetic Dipole Moment $\vec{m} = IA\vec{a}_n$
Polarization $\vec{P} = \epsilon_o(\epsilon_r - 1)\vec{E}$ $\vec{P} = \frac{\epsilon_r - 1}{\epsilon_r}\vec{D} = \frac{n\vec{p}}{V}$	Magnetization $\vec{M} = (\mu_r - 1)\vec{H}$ $\vec{M} = \frac{I_m}{l}$
Electric Susceptibility $\chi_e = \epsilon_r - 1$	Magnetic Susceptibility $\chi_m = \mu_r - 1$
Energy Stored in Capacitor $W_E = \frac{1}{2}CV^2$ $\nabla \cdot \vec{D} = \rho_v$	Energy Stored in Inductor $W_H = \frac{1}{2}LI^2$ $\nabla \cdot \vec{B} = 0$
DC Electric Field Intensity $E = \frac{V}{l}$	DC Magnetic Field Intensity $H = \frac{NI}{l} = \frac{I_c}{l}$
Electric Boundary Conditions Conductors $E_t = 0, D_N = \epsilon E_N = \rho_s : E_N = -\nabla V$	Magnetic Boundary Conditions - -
Dielectric $E_{t1} = E_{t2}, D_{n1} = D_{n2}$ $\epsilon_1 E_{n1} = \epsilon_2 E_{n2}$ $\frac{tan\theta_1}{tan\theta_2} = \frac{\epsilon_1}{\epsilon_2}$	- - - -

Common Formulas

- Electric Field due Point Charge

$$\vec{E} = \frac{Q}{4\pi\epsilon R^2}\vec{a}_R$$

- Electric Potential due Point Charge

$$V = \frac{Q}{4\pi\epsilon R}$$

- Electric Field due Infinite Line Charge

$$\vec{E} = \frac{\rho_l}{2\pi\epsilon\rho}\vec{a}_\rho$$

- Electric Field due Infinite Plane Charge

$$\vec{E} = \frac{\rho_s}{2\epsilon}\vec{a}_n$$

- Magnetic Field due Infinite Line Current

$$\vec{H} = \frac{I}{2\pi\rho}\vec{a}_\phi$$

Other Formulas

- Charge

$$Q = \begin{cases} \int \rho_L dL & \text{Line,} \\ \int \rho_S dS & \text{Surface,} \\ \int \rho_V dV & \text{Volume.} \end{cases}$$

- Electric Flux Density $\vec{D} = \frac{d\psi}{ds}\vec{a}_\psi$
- Electric Work $W = -Q\int \vec{E} \cdot d\vec{L} = QV$
- Electric Potential $V_{AB} = V_A - V_B = -\int_B^A \vec{E} \cdot d\vec{L}$
- Electric Potential with Field $\vec{E} = -\nabla V$
- Poisson Equation $\nabla^2 V = \frac{-\rho}{\epsilon}$
- Laplace Equation $\nabla^2 V = 0$
- Electric Energy $U = \frac{1}{2}\sum QV = \frac{1}{2}\int \rho_v V dv$
- Force in Conductors

$$\vec{F} = m\vec{a} = -e\vec{E}, \vec{a} = \frac{\vec{v}_d}{\tau}, \vec{v}_d = -\frac{e\tau}{m}\vec{E} = -\mu_e \vec{E}$$

- Current and Current Density $\vec{J} = \sigma\vec{E} = \rho_e \vec{v}_d = -\mu_e \rho_e \vec{E}$
- Current $I = \int \vec{J} \cdot d\vec{S}$
- $n(\text{electron/m}^3) = \frac{\rho(\text{Density})N_A(\text{Avogadro's number})}{M_g\ (\text{atomic mass})}$
- Electron Density $\rho_e = en$
- Ohm's Law $R = \frac{V}{I} = \frac{\int \vec{E} \cdot d\vec{L}}{\int \sigma \vec{E} \cdot d\vec{S}}$
- Continuity of Current $\nabla \cdot \vec{J} = -\frac{\partial \rho_v}{\partial t} \iff \oint \vec{J} \cdot d\vec{S} = -\frac{dQ}{dt}$
- Current Elements due to Magnet

$$F = -I\oint \vec{B} \times d\vec{L}, F = I(\vec{L} \times \vec{B}) \quad \text{for straight conductor}$$

- Torque due to Magnet $\vec{T} = \vec{R} \times \vec{F} = \vec{R} \times (I(\vec{L} \times \vec{B}))$
- Torque due to Magnetic dipole $\vec{T} = \vec{m} \times \vec{B}$
- Current due to electron spin $I = e\frac{\omega}{2\pi}$
- Faraday's Law $V = NA\frac{dB}{dt}$

Serious Notes

- **Ch.1**
  - Convert from any system to Cartesian then covert back if you have points and need vector between.
  - For Cartesian Indicates by three planes.
  - For Cylindrical Indicates by two planes and Cylinder.
  - For Spherical Indicates by Sphere, Convex and plane.
  - Magnitude is the same in all systems.
- **Ch.2**
  - $\int \frac{dx}{(a^2+x^2)^{3/2}} = \frac{x}{a^2\sqrt{x^2+a^2}}$
  - $\int \frac{xdx}{(a^2+x^2)^{3/2}} = \frac{-1}{\sqrt{x^2+a^2}}$
  - $\int \frac{dx}{a^2+x^2} = \frac{1}{a}tan^{-1}(\frac{x}{a})$
- **Ch.3**
  - Length with D is changeable anywhere but isn't for Q.
  - Flux lines = Q $[C]$
  - Flux density $[C/m, C/m^2 C/m^3]$

- **Ch.4**
  - Potential and Work are independent of path.
  - $\nabla V = -\vec{E}$ is normal to equipotential surface and V is max when $d\vec{L}$ in the same diraction.
  - Work is done by system if it is (-ve).
  - Workdone for putting first charge = 0
- **Ch.5**
  - Charge on the surface of conductor is equal any where and no charge inside so $\vec{E} = 0$.
  - Charging the inside charging the surface by negative Q.
- **Ch.6**
  - After adding dielectric material we get:

$$Q = Q_o + Q_p$$

$$\vec{D} = \vec{D}_o + \vec{P}$$
$$\epsilon_o \epsilon_r \vec{E} = \epsilon_o \vec{E}_o + \vec{P}$$
$$\vec{P} = \epsilon_o (\epsilon_r - 1)\vec{E}$$

  - Dielectric have charges on surface and inside.
  - Dipole direction form (-ve) to (+ve).
  - Q' = Q after removing the dielectric and battery.
  - Electric Field inside dielectric < External Field.
- **Ch.7**
  - After adding dielectric material we get:

$$\phi = \phi_o + \phi_m$$

$$\vec{B} = \vec{B}_o + \vec{B}_m$$
$$\mu_o \mu_r \vec{H} = \mu_o \vec{H}_o + \mu_o \vec{M}$$
$$\vec{M} = (\mu_r - 1)\vec{H}$$

  - The magnetization forms surface current.
  - Magnetization direction is normal.
  - Cylindrical $\vec{r} \times \vec{\phi} = \vec{z}, \vec{\phi} \times \vec{z} = \vec{r}, \vec{z} \times \vec{r} = \vec{\phi}$
  - Spherical $\vec{r} \times \vec{\theta} = \vec{\phi}, \vec{\theta} \times \vec{\phi} = \vec{r}, \vec{\phi} \times \vec{r} = \vec{\theta}$
  - Toroid Coil is same as Normal Coil as $l_{\text{coil}} = 2\pi r_{\text{toroid}}$
  - No monopole existence.
  - Magnetic Field rotate the electrons in circular motion between electric field accelerate/decelerate electrons.
  - Workdone by Magnetic Field on proton > 0
  - As $\nabla \cdot \vec{B} = 0$, So B has no sink/start or source/end and As $\nabla \times \vec{E} = 0$ So, E has no rotations.