SEE 2523 Theory Electromagnetic

Chapter 1 Electromagnetic Introduction and Vector Analysis

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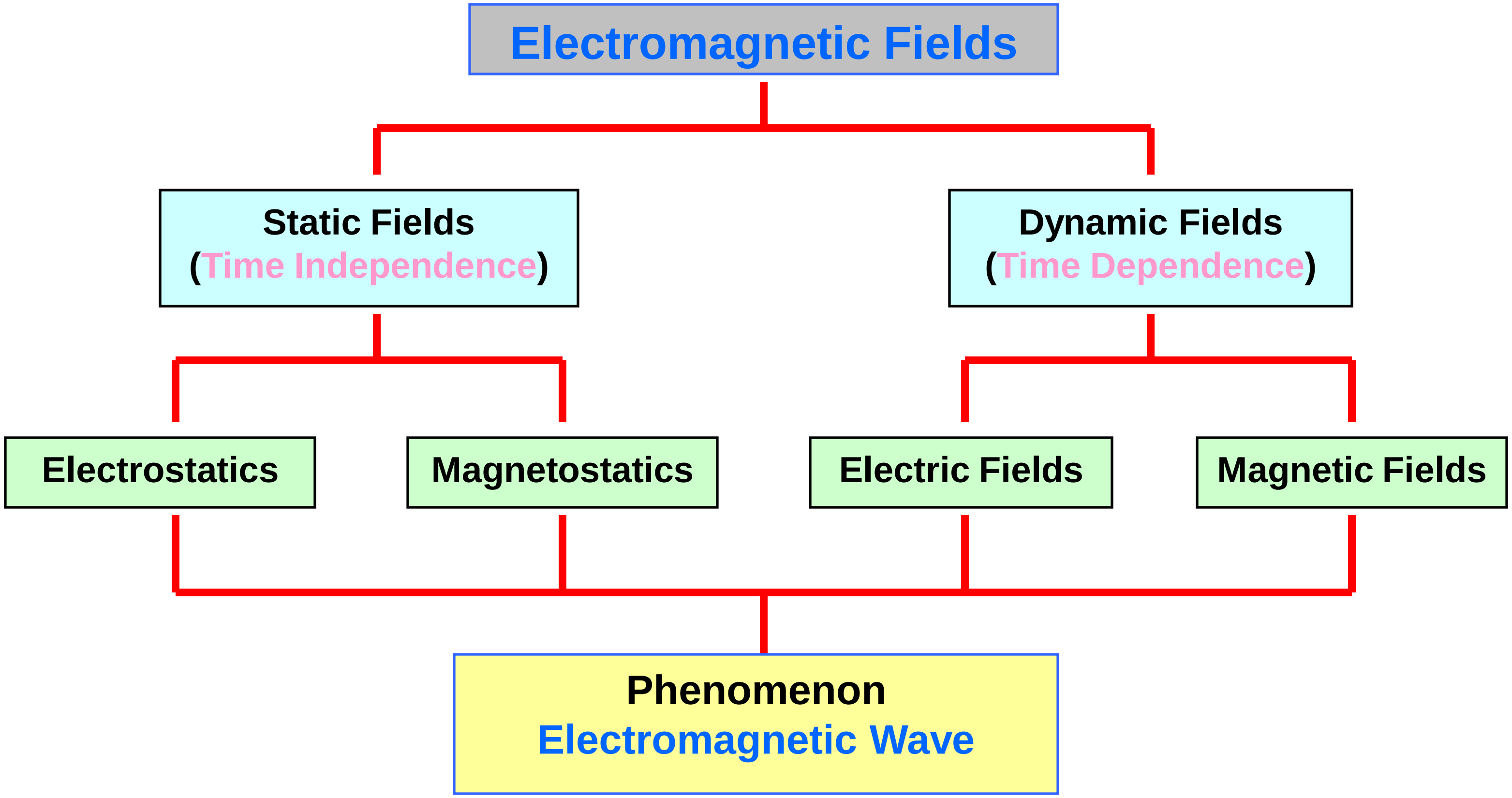
Brief Flow Chart for Electromagnetic Study



Electromagnetics (EM) is a branch of physics or electrical engineering in which electric and magnetic phenomena are studied

Basis of Electromagnetic Laws

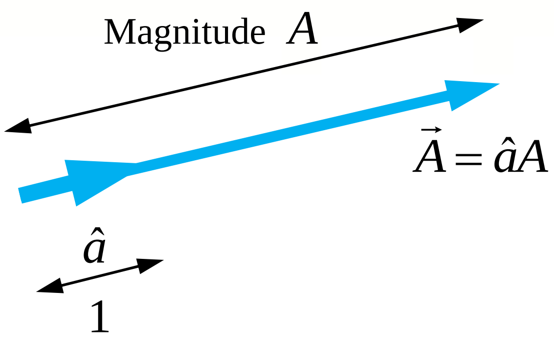
	Description	Study Chapter	Critical Experiment
Gauss's Law (electric fields)	Charge and Electric fields	Electrostatic / Electric fields	Charge repel and attract different charges. Comply with the inverse square law. Charge on an insulated conductor moves outward surface.
Gauss's Law (magnetic fields)	Magnetic fields	Magnetostatic Magnetic fields	Confirmed that only exist magnetic dipole. (naturedly no magnetic monopole)
Faraday's Law	The electrical effect of a changing magnetic fields	Magnetic induction	The bar magnet is pushed through a closed loop of wire will produce a current in the loop.
Ampere's Law	The magnetic effect of a changing electric fields	Magnetic fields	The current in the wire produces a magnetic field close to the wire.

Basic Law of Vector (1)

1. A vector $\vec{A}$ has a

   a) magnitude $A = \left|\vec{A}\right|$

   b) direction specified by a unit vector $\hat{a}$



2. A vector $\vec{A}$

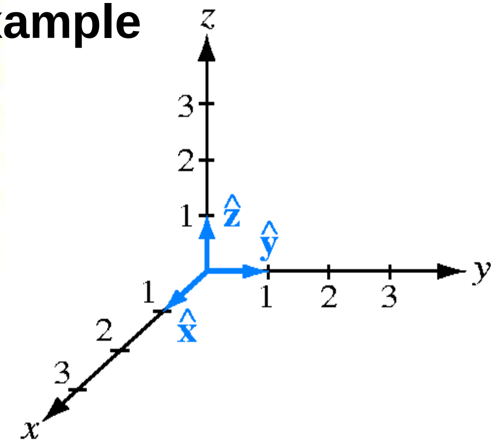
$$\vec{A} = \hat{a}\left|\vec{A}\right| = \hat{a}A$$

3. The unit vector $\hat{a}$ is given by

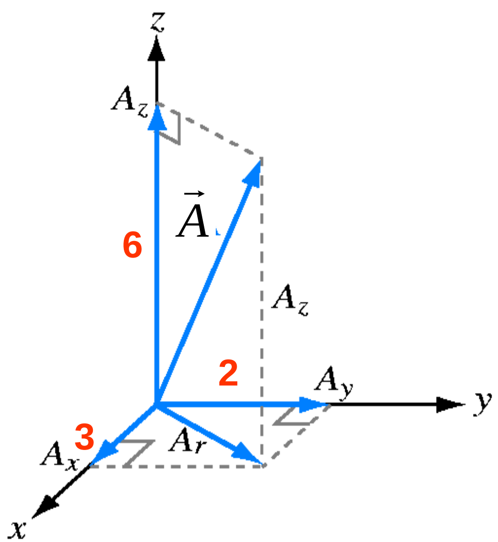
$$\hat{a} = \frac{\vec{A}}{\left|\vec{A}\right|} = \frac{\vec{A}}{A}$$

Basic Law of Vector (2)

Example



Basic vector



Components of vector $\vec{A}$

The vector $\vec{A}$ may be represented as:

$$\vec{A} = \hat{x}A_x + \hat{y}A_y + \hat{z}A_z$$

$$\vec{A} = \hat{x}3 + \hat{y}2 + \hat{z}6$$

The magnitude of $\vec{A}$

$$A = \left|\vec{A}\right| = \sqrt{A_x^2 + A_y^2 + A_z^2}$$

$$A = \sqrt{3^2 + 2^2 + 6^2} = 7$$

The direction of $\vec{A}$

$$\hat{a} = \frac{\vec{A}}{A} = \frac{\hat{x}A_x + \hat{y}A_y + \hat{z}A_z}{\sqrt{A_x^2 + A_y^2 + A_z^2}}$$

$$\hat{a} = \frac{\hat{x}3 + \hat{y}2 + \hat{z}6}{7} = \hat{x}0.429 + \hat{y}0.286 + \hat{z}0.857$$

Vector Multiplication (1)

1. There are two types of vector multiplication:

   a) Scalar (or **dot**) product $\vec{A}\cdot\vec{B}$

   b) Vector (or **cross**) product $\vec{A}\times\vec{B}$

2. The dot product of two vectors $\vec{A}$ and $\vec{B}$ is expressed as:

$$\vec{A}\cdot\vec{B} = AB\cos\theta$$

where θ is the smaller angle between $\vec{A}$ and

3. If $\vec{A}=\left(A_x,\, A_y,\, A_z\right)$ and $\vec{B}=\left(B_x,\, B_y,\, B_z\right)$

$$\vec{A}\cdot\vec{B} = A_xB_x + A_yB_y + A_zB_z$$

Vector Multiplication (2)

4. Two vectors $\vec{A}$ and $\vec{B}$ are said to be orthogonal (perpendicular) with each other, if $\vec{A}\cdot\vec{B}=0$

5. The cross product of two vectors $\vec{A}$ and $\vec{B}$ is expressed as:

$$\vec{A}\times\vec{B}=AB\sin\theta\ \hat{a}_n$$

where $\hat{a}_n$ is a unit vector normal to the plane containing $\vec{A}$ and $\vec{B}$

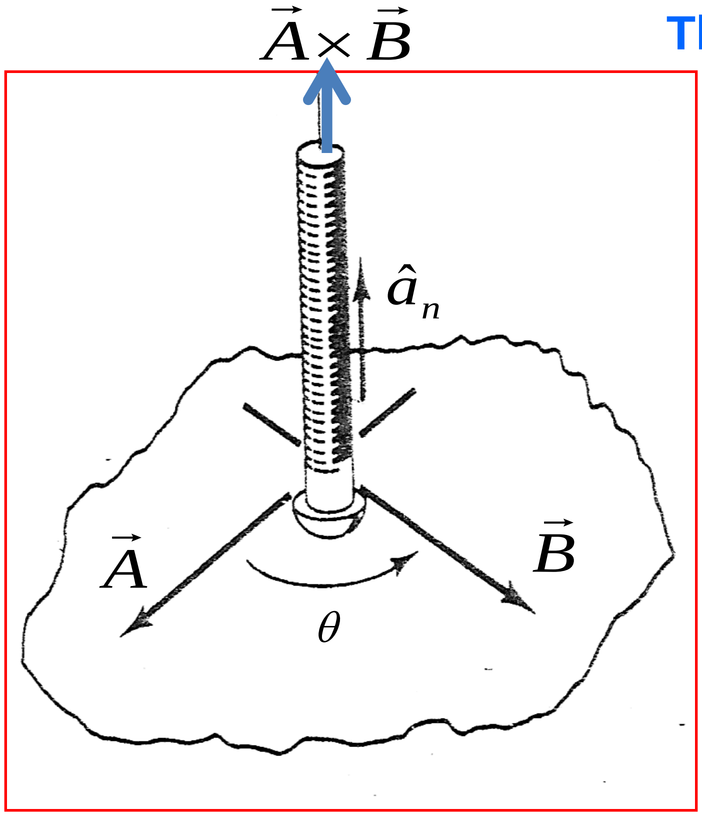
6. If $\vec{A}=\left(A_x,\,A_y,\,A_z\right)$ and $\vec{B}=\left(B_x,\,B_y,\,B_z\right)$

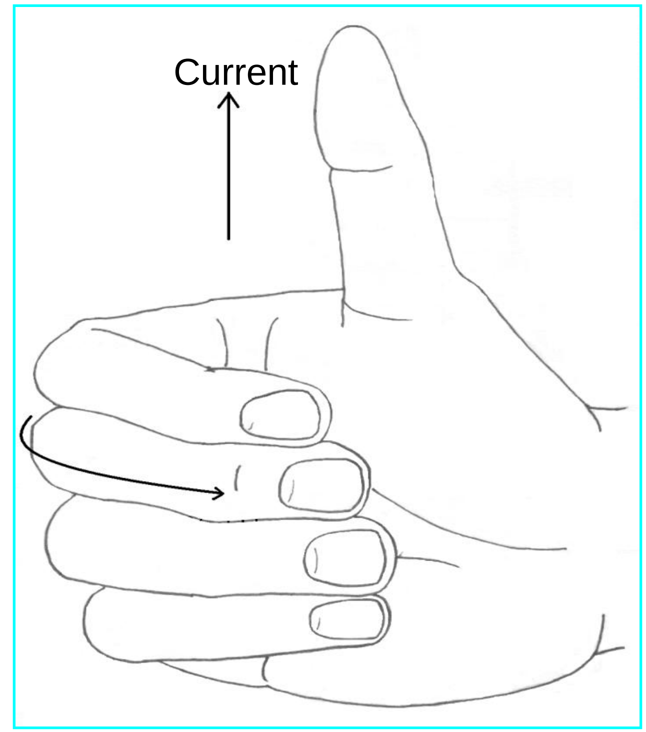
$$\vec{A}\times\vec{B}=\begin{vmatrix}\hat{a}_x & \hat{a}_y & \hat{a}_z\\ A_x & A_y & A_z\\ B_x & B_y & B_z\end{vmatrix}$$

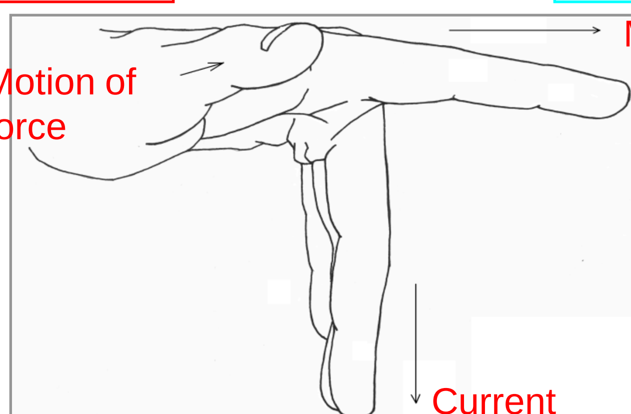
$$=\left(A_yB_z-A_zB_y\right)\hat{a}_x+\left(A_zB_x-A_xB_z\right)\hat{a}_y+\left(A_xB_y-A_yB_x\right)\hat{a}_z$$

Vector Multiplication (3)

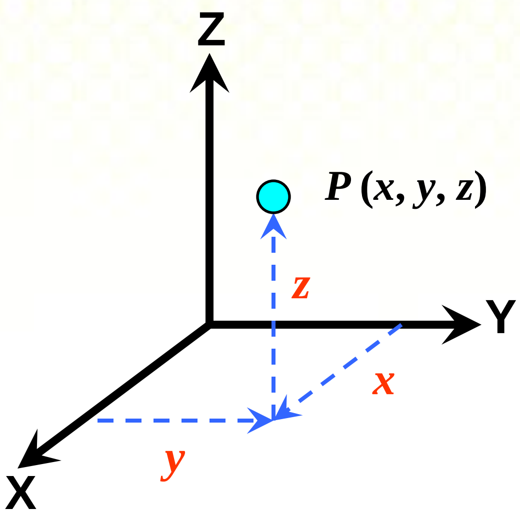
The cross product

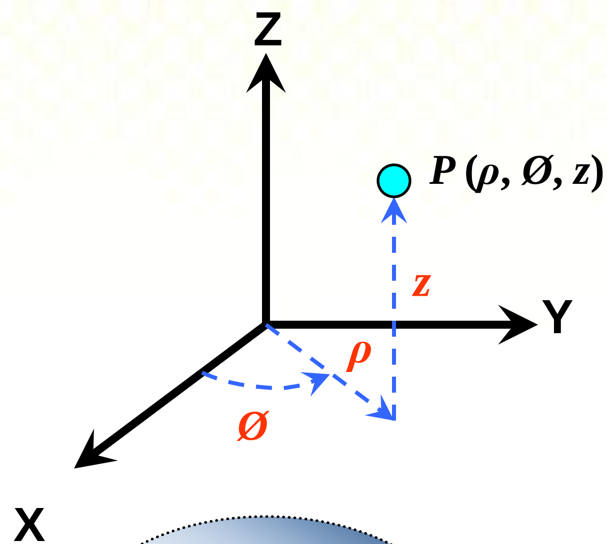


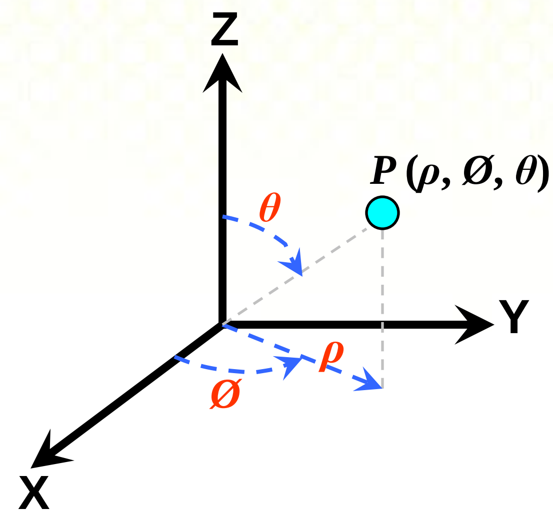


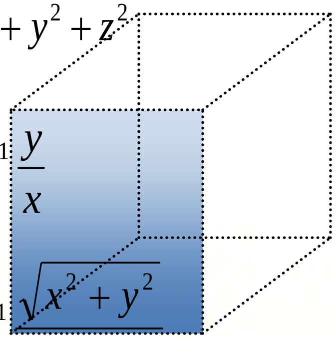


Orthogonal Coordinate Systems









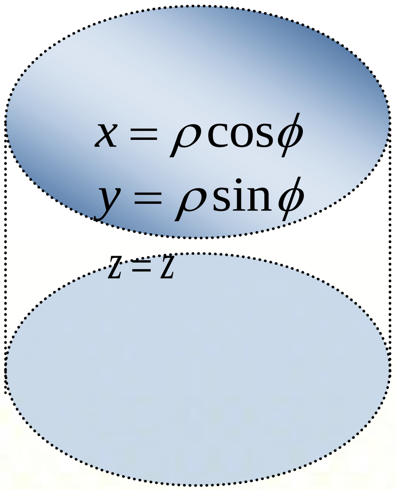
$$\rho = \sqrt{x^2 + y^2 + z^2}$$

$$\phi = \tan^{-1}\frac{y}{x}$$

$$\theta = \tan^{-1}\frac{\sqrt{x^2 + y^2}}{z}$$

$$z = z$$

Cartesian

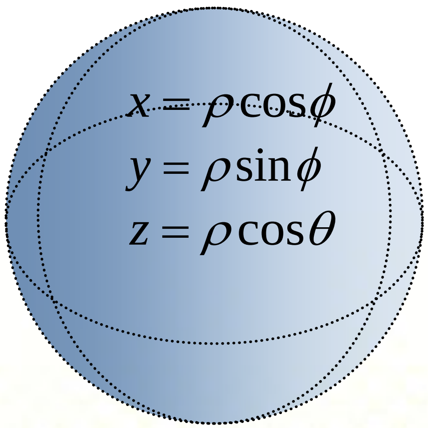


$$x = \rho\cos\phi$$

$$y = \rho\sin\phi$$

$$z = z$$

Cylindrical



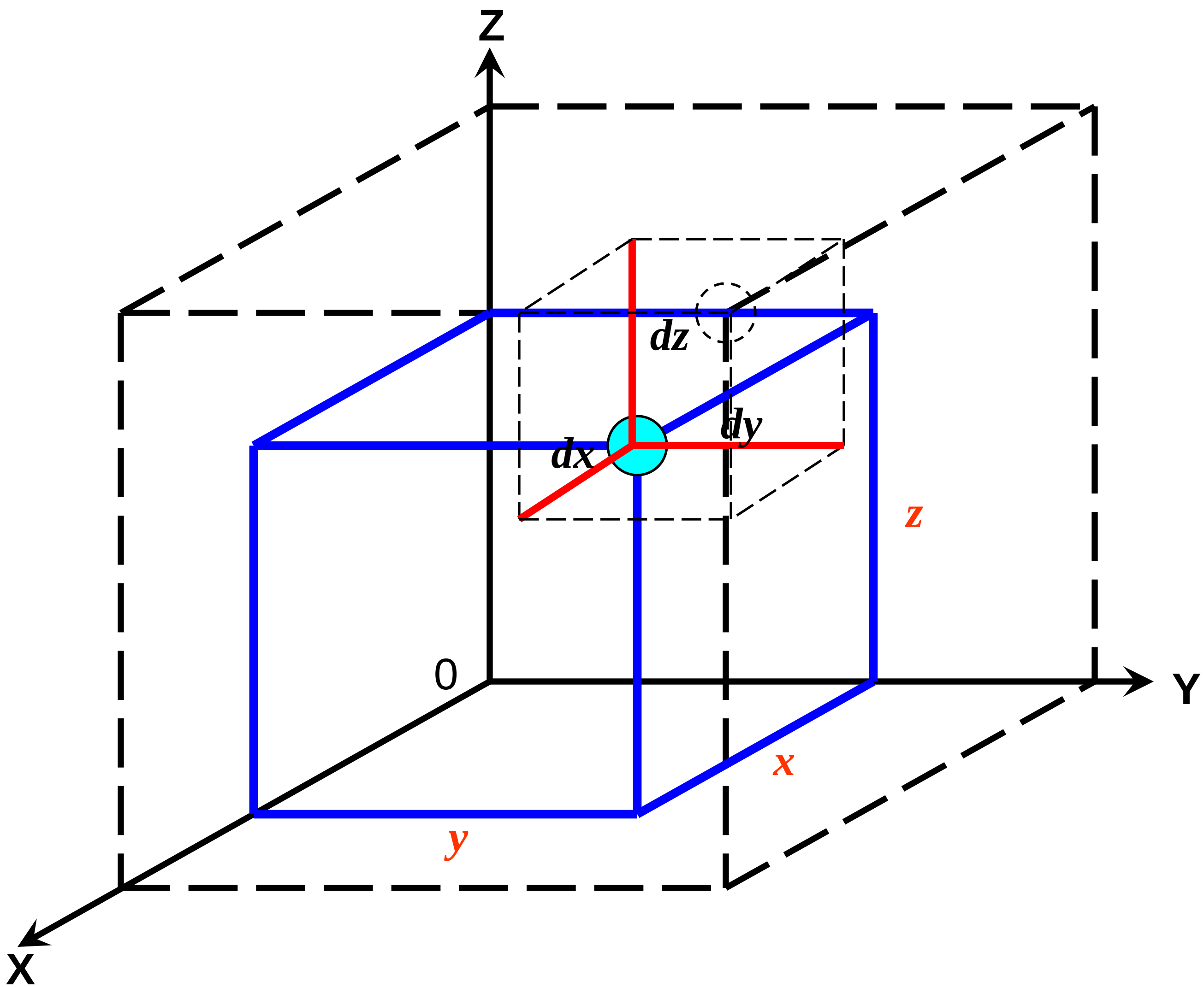
$$x = \rho\cos\phi$$

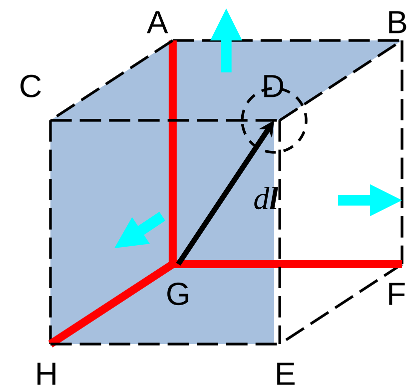
$$y = \rho\sin\phi$$

$$z = \rho\cos\theta$$

Spherical

Length, Area and Volume in Cartesian Coordinates





$$dv = dx\,dy\,dz$$

$$d\vec{S}_{ABCD} = \hat{z}\,dx\,dy$$

$$d\vec{S}_{HCDE} = \hat{x}\,dy\,dz$$

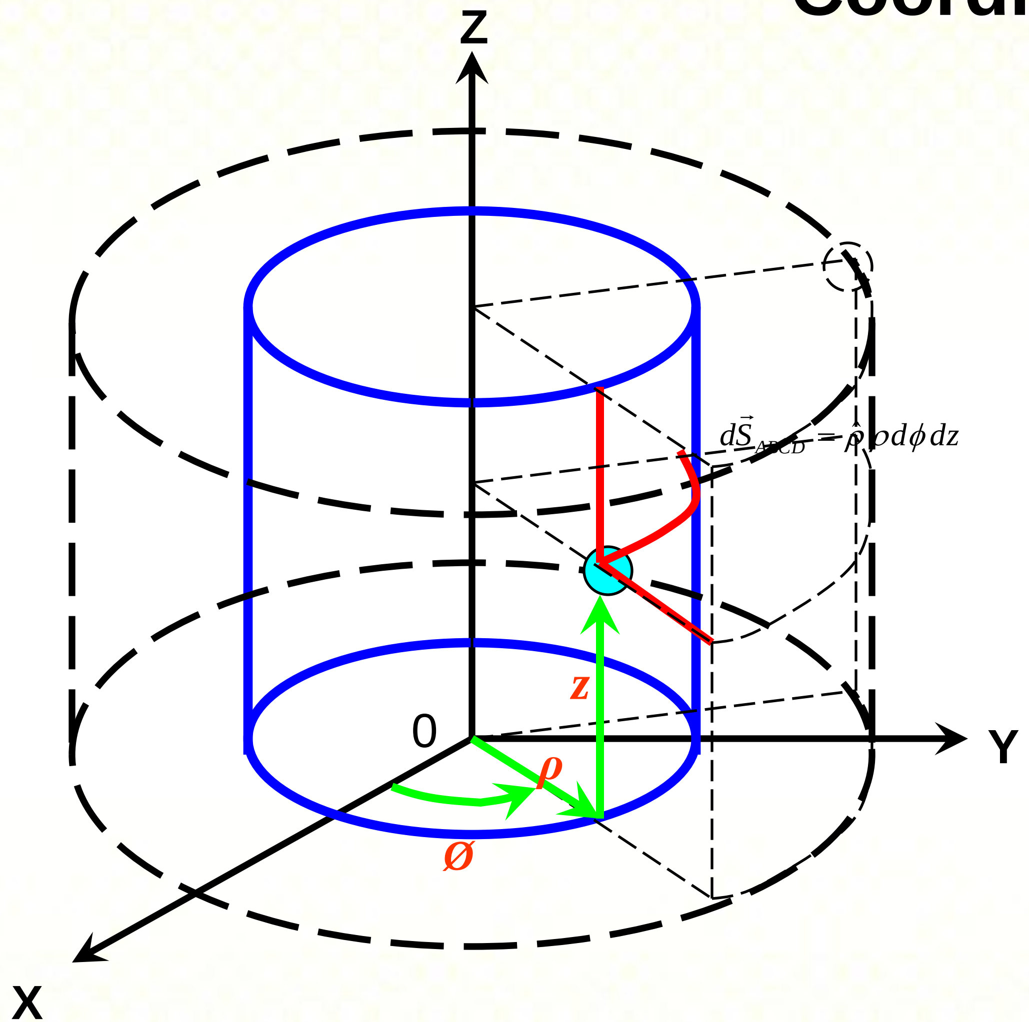
$$d\vec{S}_{FBDE} = \hat{y}\,dx\,dz$$

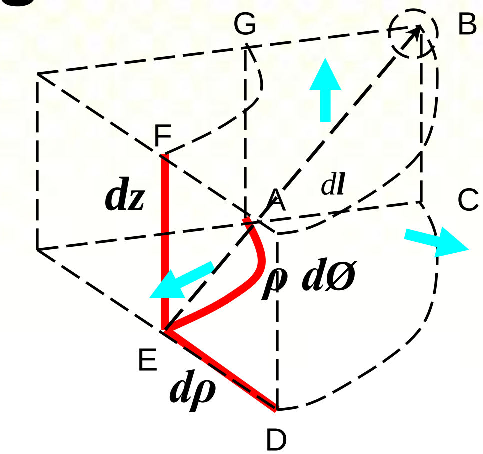
$$d\vec{l} = \hat{x}dx + \hat{y}dy + \hat{z}\,dz$$

$$dl^2 = dx^2 + dy^2 + dz^2$$

P **point is expanded from (*x*, *y*, *z*) to (*x*+dx, *y*+dy, z+dz).**

Length, Area and Volume in Cylindrical Coordinates





$$dv = \rho\, d\rho\, d\phi\, dz$$

$$d\vec{S}_{ADEF} = \hat{\phi}\, d\rho\, dz$$

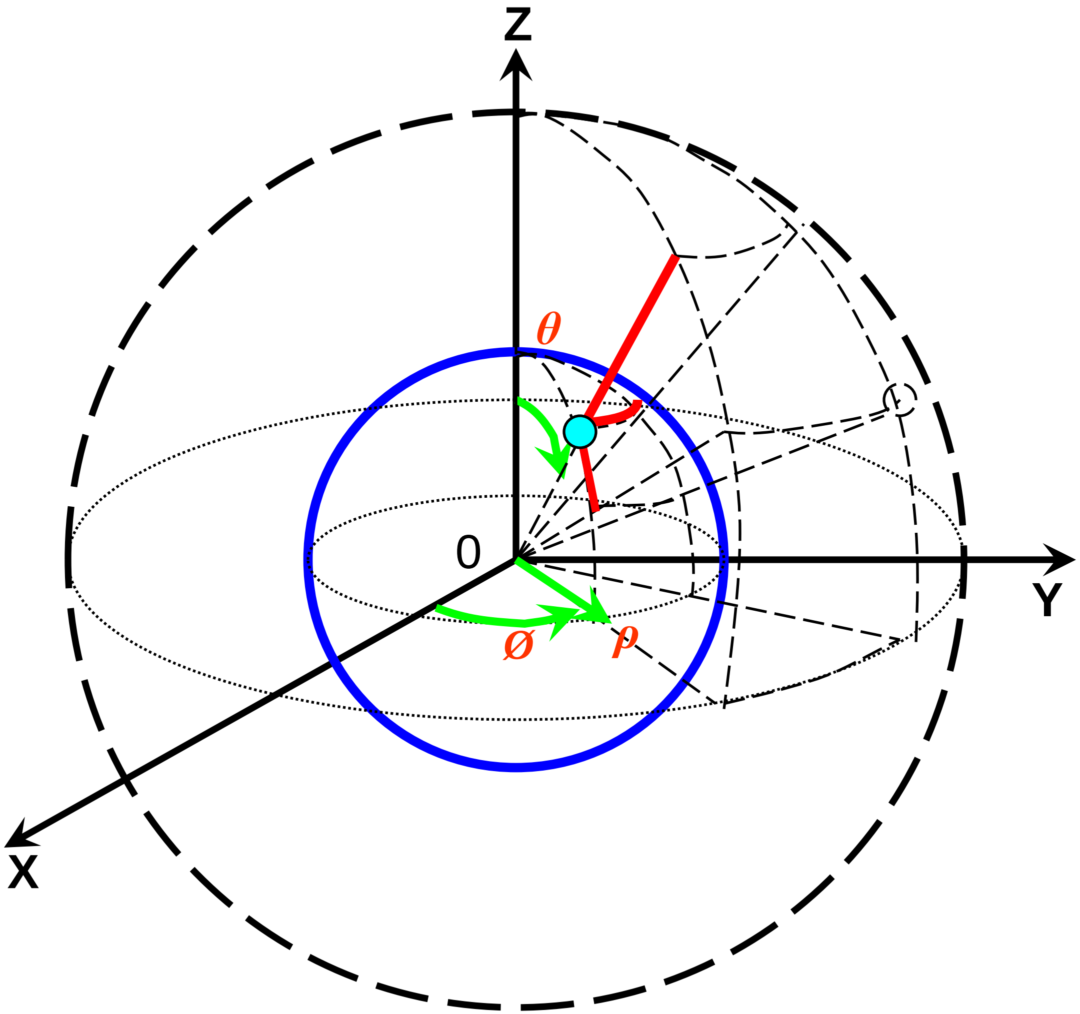
$$d\vec{S}_{AFGB} = \hat{z}\, \rho\, d\rho\, d\phi$$

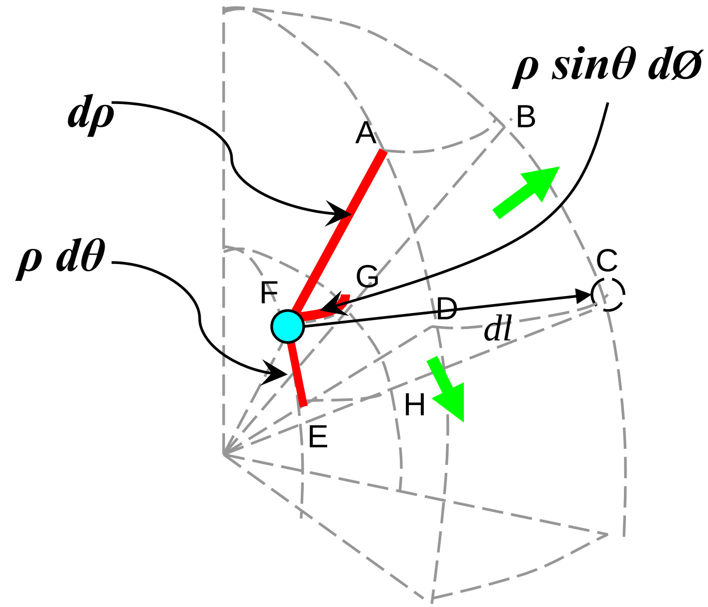
$$d\vec{l} = \hat{\rho}\, d\rho + \hat{\phi}\, \rho\, d\phi + \hat{z}\, dz$$

$$dl^2 = d\rho^2 + \rho^2 d\phi^2 + dz^2$$

P **point is expanded from (*ρ*, *Ø*, *z*) to (*ρ*+d*ρ*, *Ø* +d*Ø*, *z*+d*z*).**

Length, Area and Volume in Spherical Coordinates





$$dv = \rho^2 \sin\theta \, d\rho \, d\theta \, d\phi$$

$$d\vec{S}_{ABCD} = \hat{\rho} \, \rho^2 \sin\theta \, d\theta \, d\phi$$

$$d\vec{S}_{CDEH} = \hat{\theta} \, \rho \sin\theta \, d\rho \, d\phi$$

$$d\vec{S}_{BCHG} = \hat{\phi} \, \rho \, d\rho \, d\theta$$

$$d\vec{l} = \hat{\rho} \, d\rho + \hat{\theta} \, \rho \, d\theta + \hat{\phi} \, \rho \sin\theta \, d\phi$$

$$dl^2 = d\rho^2 + \rho^2 d\theta^2 + \rho^2 \sin^2\theta \, d\phi^2$$

P **point is expanded from (ρ, θ, Ø) to (ρ+dρ, θ+dθ, Ø+dØ).**

The electromagnetic (static) problem cases

Coordinate	The problems most often encountered	
	Electrostatic Cases	Magnetostatic Cases
Cartesian	- Any uniform charge distribution using a scale of cartesian coordinates.	- The current flowing on the horizontal infinite extent plane.
Cylindrical	- Uniform charge distribution on cylindrical conductor. - Uniform charge distribution on the infinite length of line. - Uniform charge distribution on the infinite extent horizontal plane. - Uniform charge distribution on the horizontal circle plane. - Uniform charge distribution on the circle line.	- The current flowing in circumference. - The current flowing in an infinite straight line. - The current flows in the solenoid and toroid.
Spherical	- Uniform charge distribution on the surface of a sphere. - Uniform charge distribution of the point.	- Problem for the case of spheres less found.

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