GOVERNING EQUATIONS FOR CLASSICAL ELECTROMAGNETICS

UTEP

Pioneering 21st Century Electromagnetics and Photonics

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EM LAB

	Integral Form	Differential Form	Name
Time-Domain	$Q_e(t)=\oiint_S \vec{D}(t)\bullet d\vec{s}=\iiint_V \rho_v(t)\,dv$	$\nabla\bullet\vec{D}(t)=\rho_v(t)$	Gauss' Law
	$\oiint_S \vec{B}(t)\bullet d\vec{s}=0$	$\nabla\bullet\vec{B}(t)=0$	No Magnetic Charge
	$V_{\text{emf}}(t)=\oint_L \vec{E}(t)\bullet d\vec{\ell}=-\iint_S\left[\frac{\partial\vec{B}(t)}{\partial t}\right]\bullet d\vec{s}$	$\nabla\times\vec{E}(t)=-\frac{\partial\vec{B}(t)}{\partial t}$	Faraday's Law
	$I(t)=\oint_L \vec{H}(t)\bullet d\vec{\ell}=\iint_S\left[\vec{J}(t)+\frac{\partial\vec{D}(t)}{\partial t}\right]\bullet d\vec{s}$	$\nabla\times\vec{H}(t)=\vec{J}(t)+\frac{\partial\vec{D}(t)}{\partial t}$	Ampere's Circuit Law
	$\oiint_S \vec{J}\bullet d\vec{s}=-\frac{\partial Q_e}{\partial t}$	$\nabla\bullet\vec{J}=-\frac{\partial\rho_v}{\partial t}$	Continuity of Current
	$\vec{D}(t)=[\varepsilon(t)]*\vec{E}(t)$ Electric Response $\vec{B}(t)=[\mu(t)]*\vec{H}(t)$ Magnetic Response		Constitutive Relations
Frequency-Domain	$Q_e=\oiint_S \vec{D}\bullet d\vec{s}=\iiint_V \rho_v dv$	$\nabla\bullet\vec{D}=\rho_v$	Gauss' Law
	$\oiint_S \vec{B}\bullet d\vec{s}=0$	$\nabla\bullet\vec{B}=0$	No Magnetic Charge
	$V_{\text{emf}}=\oint_L \vec{E}\bullet d\vec{\ell}=-\iint_S[j\omega\vec{B}]\bullet d\vec{s}$	$\nabla\times\vec{E}=-j\omega\vec{B}$	Faraday's Law
	$I=\oint_L \vec{H}\bullet d\vec{\ell}=\iint_S[\vec{J}+j\omega\vec{D}]\bullet d\vec{s}$	$\nabla\times\vec{H}=\vec{J}+j\omega\vec{D}$	Ampere's Circuit Law
	$\oiint_S \vec{J}\bullet d\vec{s}=-j\omega Q_e$	$\nabla\bullet\vec{J}=-j\omega\rho_v$	Continuity of Current
	$\vec{D}=[\varepsilon]\vec{E}$ Electric Response $\vec{B}=[\mu]\vec{H}$ Magnetic Response		Constitutive Relations

Parameter Definitions

Electric Field Intensity, E (V/m)

Electric Flux Density, D (C/m^2)

Magnetic Field Intensity, H (A/m)

Magnetic Flux Density, B (Wb/m^2)

Electric Current Density, J (A/m^2)

Volume Charge Density, ρ_v (C/m^3)

Permittivity, ε (F/m)

Permeability, μ (H/m)

Electrical Conductivity, σ (1/Ω·m)

Constants

Permittivity: $[\varepsilon]=\varepsilon_0[\varepsilon_r]$

$\varepsilon_0=8.8541878176\times10^{-12}$ (F/m)

Permeability: $[\mu]=\mu_0[\mu_r]$

$\mu_0\approx4\pi\times10^{-7}$ (H/m)

$\mu_0=1.2566370614\times10^{-6}$ (H/m)

Impedance: $\eta_0\approx120\pi$ (Ω)

$\eta_0=376.73031346177$ (Ω)

Speed of Light: $c_0=299,792,458$ (m/s)

Lorentz Force Law

$$\vec{F}=q\vec{E}+q\left(\vec{v}\times\vec{B}\right)$$

Sign Convention

e^{-jkz} For propagation in the +z direction.