Governing Equations for Classical Electrodynamics

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	Integral Form	Differential Form	Name
Time-Domain Form	$Q_e(t) = \oiint_S \vec{D}(t) \cdot d\vec{s} = \iiint_V \rho_v(t) dv$	$\nabla \cdot \vec{D}(t) = \rho_v(t)$	Gauss' Law
	$\oiint_S \vec{B}(t) \cdot d\vec{s} = 0$	$\nabla \cdot \vec{B}(t) = 0$	Gauss' Law for Magnetic Fields
	$V_{emf}(t) = \oint_L \vec{H}(t) \cdot d\vec{\ell} = -\iint_S \left[\frac{\partial \vec{B}(t)}{\partial t}\right] \cdot d\vec{s}$	$\nabla \times \vec{E}(t) = -\frac{\partial \vec{B}(t)}{\partial t}$	Faraday's Law
	$I(t) = \oint_L \vec{E}(t) \cdot d\vec{\ell} = \iint_S \left[\vec{J}(t) + \frac{\partial \vec{D}(t)}{\partial t}\right] \cdot d\vec{s}$	$\nabla \times \vec{H}(t) = \vec{J}(t) + \frac{\partial \vec{D}(t)}{\partial t}$	Ampere's Circuit Law
	$\oiint_S \vec{J}(t) \cdot d\vec{s} = -\frac{\partial Q_e(t)}{\partial t}$	$\nabla \cdot \vec{J}(t) = -\frac{\partial \rho_v(t)}{\partial t}$	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 Form	$Q_e = \oiint_S \vec{D} \cdot d\vec{s} = \iiint_V \rho_v dv$	$\nabla \cdot \vec{D} = \rho_v$	Gauss' Law
	$\oiint_S \vec{B} \cdot d\vec{s} = 0$	$\nabla \cdot \vec{B} = 0$	Gauss' Law for Magnetic Fields
	$V_{emf} = \oint_L \vec{H} \cdot d\vec{\ell} = -\iint_S \left[j\omega\vec{B}\right] \cdot d\vec{s}$	$\nabla \times \vec{E} = -j\omega\vec{B}$	Faraday's Law
	$I = \oint_L \vec{E} \cdot d\vec{\ell} = \iint_S \left[\vec{J} + j\omega\vec{D}\right] \cdot d\vec{s}$	$\nabla \times \vec{H} = \vec{J} + j\omega\vec{D}$	Ampere's Circuit Law
	$\oiint_S \vec{J} \cdot d\vec{s} = -j\omega Q_e$	$\nabla \cdot \vec{J} = -j\omega\rho_v$	Continuity of Current
	$\vec{D} = [\varepsilon]\vec{E}$ Electric Response $\vec{B} = [\mu]\vec{H}$ Magnetic Response		Constitutive Relations

Parameter Definitions

$\vec{E}$ (V/m)	Electric Current Density
$\vec{D}$ (C/m^2)	Electric Flux Density
$\vec{H}$ (A/m)	Magnetic Field Intensity
$\vec{B}$ (W/m^2)	Magnetic Flux Density
$\vec{J}$ (A/m^2)	Electric Current Density
ρ_v (C/m^3)	Volume Charge Density
ε (F/m)	Permittivity
μ (H/m)	Permeability
σ ($1/\Omega \cdot$ m)	Electrical Conductivity

Sign Convention

Negative sign convention

$$\exp(-jkz)$$

Lorentz Force Law

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

Constants

Free Space Permittivity $[\varepsilon] = \varepsilon_0[\varepsilon_r]$

$$\varepsilon_0 = 8.8541878176 \times 10^{-12} \text{ F/m}$$

Free Space Permeability $[\mu] = \mu_0[\mu_r]$

$$\mu_0 = 4\pi \times 10^{-7} \text{ H/m}$$

$$\mu_0 = 1.2566370614 \times 10^{-6} \text{ H/m}$$

Free Space Impedance $\eta_0 \approx 120\pi\ \Omega$

$$\eta_0 = 376.73031346177\ \Omega$$

Speed of Light in Vacuum $c_0 = 299{,}792{,}458$ m/s