

Governing Equations for Classical Electrodynamics

	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
	$V_{emf}(t) = \oint_L \vec{E}(t) \cdot d\vec{\ell} = - \iint_S \left[\frac{\partial \vec{B}(t)}{\partial t} \right] \cdot d\vec{s}$	$\nabla \times \vec{E}(t) = - \frac{\partial \vec{B}(t)}{\partial t}$	Faraday's Law
	$I(t) = \oint_L \vec{H}(t) \cdot d\vec{\ell} = \iint_S \left[\vec{j}(t) + \frac{\partial \vec{D}(t)}{\partial t} \right] \cdot d\vec{s}$	$\nabla \times \vec{H}(t) = \vec{j}(t) + \frac{\partial \vec{D}(t)}{\partial t}$	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
	$\vec{D}(t) = [\epsilon(t)] * \vec{E}(t)$ $\vec{B}(t) = [\mu(t)] * \vec{H}(t)$	Electric Response 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
	$V_{emf} = \oint_L \vec{E} \cdot d\vec{\ell} = - \iint_S [j\omega \vec{B}] \cdot d\vec{s}$	$\nabla \times \vec{E} = -j\omega \vec{B}$	Faraday's Law
	$I = \oint_L \vec{H} \cdot d\vec{\ell} = \iint_S [\vec{j} + j\omega \vec{D}] \cdot d\vec{s}$	$\nabla \times \vec{H} = \vec{j} + j\omega \vec{D}$	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
	$\vec{D} = [\epsilon] \vec{E}$ $\vec{B} = [\mu] \vec{H}$	Electric Response Magnetic Response	Constitutive Relations

Parameter Definitions

\vec{E} (V/m)	Electric Field Intensity
\vec{D} (C/m ²)	Electric Flux Density
\vec{H} (A/m)	Magnetic Field Intensity
\vec{B} (Wb/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/Ω · m)	Electrical Conductivity

Sign Convention

Negative sign convention
 $\exp(-jkz)$

Lorentz Force Law

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

Constants

Free Space Permittivity	$[\epsilon] = \epsilon_0 [\epsilon_r]$ $\epsilon_0 = 8.8541878176 \times 10^{-12}$ F/m
Free Space Permeability	$[\mu] = \mu_0 [\mu_r]$ $\mu_0 = 4\pi \times 10^{-7}$ H/m $\mu_0 = 1.2566370614 \times 10^{-6}$ 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