Maxwell's Equations

Maxwell's equations represent one of the most elegant and concise ways to state the fundamentals of electricity and magnetism. From them one can develop most of the working relationships in the field. Because of their concise statement, they embody a high level of mathematical sophistication and are therefore not generally introduced in an introductory treatment of the subject, except perhaps as summary relationships.

These basic equations of electricity and magnetism can be used as a starting point for advanced courses, but are usually first encountered as unifying equations after the study of electrical and magnetic phenomena.

Symbols Used		
E = Electric field	ρ = charge density	i = electric current
B = Magnetic field	ε_0 = permittivity	J = current density
D = Electric displacement	μ_0 = permeability	c = speed of light
H = Magnetic field strength	M = Magnetization	P = Polarization

Integral form | Differential form

Index

Maxwell's equations concepts

Maxwell's Equations

Integral form in the absence of magnetic or polarizable media:

I. Gauss' law for electricity $\oint \vec{E} \cdot d\vec{A} = \frac{q}{\varepsilon_0}$

II. Gauss' law for magnetism $\oint \vec{B} \cdot d\vec{A} = 0$

III. Faraday's law of induction $\oint \vec{E} \cdot d\vec{s} = -\frac{d\Phi_B}{dt}$

IV. Ampere's law $\oint \vec{B} \cdot d\vec{s} = \mu_0 i + \frac{1}{c^2}\frac{\partial}{\partial t}\int \vec{E} \cdot d\vec{A}$

Differential form | Discussion

Index

Maxwell's equations concepts

HyperPhysics***** Electricity and Magnetism R Nave

Go Back

Maxwell's Equations

Differential form in the absence of magnetic or polarizable media:

I. Gauss' law for electricity $\nabla \cdot E = \frac{\rho}{\varepsilon_0} = 4\pi k \rho$

II. Gauss' law for magnetism $\nabla \cdot B = 0$

III. Faraday's law of induction $\nabla x\, E = -\frac{\partial B}{\partial t}$

IV. Ampere's law
$$\nabla\, x\, B = \frac{4\pi k}{c^2} J + \frac{1}{c^2}\frac{\partial E}{\partial t} = \frac{J}{\varepsilon_0 c^2} + \frac{1}{c^2}\frac{\partial E}{\partial t}$$

$$k = \frac{1}{4\pi\varepsilon_0} = \textit{Coulomb's constant} \qquad c^2 = \frac{1}{\mu_0\varepsilon_0}$$

Integral form | Discussion

Differential form with magnetic and polarizable media

Index

Maxwell's equations concepts

HyperPhysics***** Electricity and Magnetism

R Nave

Go Back

Maxwell's Equations

Differential form with magnetic and/or polarizable media:

I. Gauss' law for electricity $\nabla \cdot D = \rho$

$D = \varepsilon_0 E + P$ *General case*

$D = \varepsilon_0 E$ *Free space*

$D = \varepsilon E$ *Isotropic linear dielectric*

II. Gauss' law for magnetism $\nabla \cdot B = 0$

III. Faraday's law of induction $\nabla x\, E = -\frac{\partial B}{\partial t}$

IV. Ampere's law $\nabla\, x\, H = J + \frac{\partial D}{\partial t}$

$B = \mu_0(H + M)$ *General case*

$B = \mu_0 H$ *Free space*

$B = \mu H$ *Isotropic linear magnetic medium*

Integral form	Discussion

Index

Maxwell's equations concepts