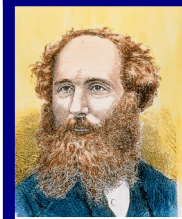
# Maxwell's Equations

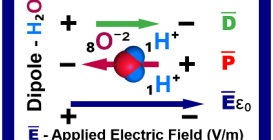


JC Maxwell
1831 – 1879

**By 1862, James Maxwell published his equations that codified known data of classical Electromagnetism. By 1891, work of Oliver Heaviside was credited with their final form.**

| | |
|---|---|
| 1st) $\nabla\bullet\mathbf{D} = \rho$ | $\oiint(\mathbf{D}\bullet\hat{\mathbf{n}}_s)ds = \iiint \rho dv$ |
| 2nd) $\nabla\bullet\mathbf{B} = 0$ | $\oiint(\mathbf{B}\bullet\hat{\mathbf{n}}_s)ds = 0$ |
| 3rd) $\nabla\times\mathbf{E} = -\partial\mathbf{B}/\partial t$ | $\oint(\mathbf{E}\bullet d\ell) = -d/dt\,[\iint(\mathbf{B}\bullet\hat{\mathbf{n}}_s)ds]$ |
| 4th) $\nabla\times\mathbf{H} = \mathbf{J}+\partial\mathbf{D}/\partial t$ | $\oint(\mathbf{H}\bullet d\ell) = \iint(\mathbf{J}\bullet\hat{\mathbf{n}}_s)ds + d/dt\,[\iint(\mathbf{D}\bullet\hat{\mathbf{n}}_s)ds]$ |

## Dielectrics



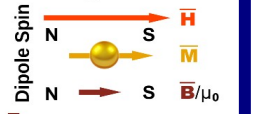

$\bar{E}$ - Applied Electric Field (V/m)
$\bar{P}$ - $H_2O$ Dipole Density (C/m²)
$\bar{D}$ - Metric Displacement (C/m²)

**These equations were developed in terrestrial settings far from the pure vacuum of outer space. In a vacuum ⇨ $\kappa = 0$ ⇨ $\mathbf{D} = \varepsilon_0\mathbf{E}$ & $\mathbf{H} = \mathbf{B}/\mu_0$. For a gas $|\kappa| < 1$:**

$\mathbf{D} \equiv \varepsilon\mathbf{E}$ & $\varepsilon / \varepsilon_0 \equiv (1-\kappa)$ ⇨ $\mathbf{P} = -\kappa\varepsilon_0\mathbf{E}$ & $\varepsilon_0\mathbf{E} = \mathbf{D}-\mathbf{P}$
$\mathbf{H} \equiv \mathbf{B}/\mu$ & $\mu_0/\mu \equiv (1+\kappa)$ ⇨ $\mathbf{M} = \kappa/\mu_0\mathbf{B}$ & $\mathbf{B}/\mu_0 = \mathbf{H}-\mathbf{M}$

**To measure Electric (E) & Magnetic (B) fields in 1800's labs, 1st order linear Dielectric (P) & Magnetic (M) dipoles were included to match lab results.**

## Magnetics




$\bar{B}$ - Applied Magnetic Flux (T)
$\bar{M}$ - Dipole Density (A/m)
$\bar{H}$ - Metric Magnetic Field (A/m)