Continuity Equation

$$\frac{\partial \rho}{\partial t} = -\nabla \cdot \mathbf{J}$$

Total Energy in EM Fields

$$\frac{1}{2}\left(\epsilon_0 E^2 + \frac{1}{\mu_0} B^2\right)$$

Poynting Vector

$$S \equiv \frac{1}{\mu_0}(\mathbf{E} \times \mathbf{B})$$

Continuity Equation 2

$$\frac{\partial u}{\partial t} = -\nabla \cdot \mathbf{S}$$

Momentum Density

$$\mu_o \epsilon_0 \mathbf{S} = \epsilon_0(\mathbf{E} \times \mathbf{B})$$

Angular Momentum

$$\vec{\ell} = \vec{r} \times \vec{g}$$

Wave Equation

$$\frac{\partial^2 f}{\partial z^2} = \frac{1}{v^2}\frac{\partial^2 f}{\partial t^2}$$

Wave Number

$$\lambda = \frac{2\pi}{k}$$

Period

$$T = \frac{2\pi}{kv}$$

Frequency

$$f = \frac{1}{T} = \frac{kv}{2\pi} = \frac{v}{\lambda}$$

Origins of Boundary Conditions

$$\int \vec{E} \cdot d\vec{l} = -\frac{d}{dt}\int \vec{B} \cdot d\vec{A} \implies E_1^{\parallel} - E_2^{\parallel} = 0$$
$$\frac{1}{\mu}\left(\vec{\nabla} \times \vec{B}\right) = \epsilon \frac{\partial E}{\partial t} \implies \frac{1}{\mu_1} B_1^{\parallel} = \frac{1}{\mu_2} B_2^{\parallel}$$
$$\vec{\nabla} \cdot \vec{B} = 0 \implies B_1^{\perp} = B_2^{\perp}$$
$$\vec{\nabla} \cdot \vec{D} = 0 \implies \epsilon_1 E_1^{\perp} = \epsilon_2 E_2^{\perp}$$

Polarization Vector

$$\hat{n} = \cos\theta \hat{x} + \sin\theta \hat{y}$$

Polarization Directions

Right Handed/Circular Polarization:
Clockwise Rotation about the $\vec{k}$ vector.
Left Handed/Circular Polarization:
Counter-Clockwise Rotation about the $\vec{k}$ vector.

Maxwell's Foundation for EM Waves

$$\nabla^2 \mathbf{E} = \mu_0 \epsilon_0 \frac{\partial^2 \mathbf{E}}{\partial t^2}$$

$$\nabla^2 \mathbf{B} = \mu_0 \epsilon_0 \frac{\partial^2 \mathbf{B}}{\partial t^2}$$

EM Waves

$$\tilde{\mathbf{E}}(\mathbf{r}, t) = \tilde{E}_0 e^{i(\mathbf{k}\cdot\mathbf{r} - \omega t)\hat{\mathbf{n}}}$$

$$\tilde{\mathbf{B}}(\mathbf{r}, t) = \frac{1}{c}\tilde{E}_0 e^{i(\mathbf{k}\cdot\mathbf{r} - \omega t)}(\hat{\mathbf{k}} \times \hat{\mathbf{n}}) = \frac{1}{c}\hat{\mathbf{k}} \times \tilde{\mathbf{E}}$$

Averages

$$\langle u \rangle = \frac{1}{2}\epsilon_0 E_0^2$$
$$\langle \mathbf{S} \rangle = \frac{1}{2} c \epsilon_0 E_0^2 \hat{\mathbf{z}}$$
$$\langle \mathbf{g} \rangle = \frac{1}{2c}\epsilon_0 E_0^2 \hat{\mathbf{z}}$$

Intensity

$$\langle S \rangle = \frac{1}{2} c \epsilon_0 E_0^2$$

Radiation Pressure

$$P = \frac{1}{A}\frac{\Delta p}{\Delta t} = \frac{1}{2}\epsilon_0 E_0^2 = \frac{I}{c}$$

Ohm's Law

$$\vec{J} = \sigma \vec{E}$$