

Symbols and Constants

\vec{F}	force	W	energy
Q	charge	I	current
ρ_V	volume charge density	\vec{j}	current density
\vec{E}	electric field	\vec{H}	magnetic field
\vec{D}	displacement field	\vec{B}	magnetic flux density field
\vec{P}	polarization field	\vec{M}	magnetization field
V	electric potential	\vec{A}	vector potential
Φ	electric or magnetic flux	\vec{S}	Poynting vector
ϵ_R	dielectric constant	μ_R	relative permeability
ϵ_0	8.854×10^{-12} F/m	μ_0	$4\pi \times 10^{-7}$ H/m

Mathematics

cylinders	volume = $\pi a^2 L$ $dV = \rho d\rho d\phi dz$	cross-section πa^2 cross-section $dS = \rho d\rho d\phi$
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spheres	volume = $(4/3)\pi a^3$ $dV = r^2 \sin \theta dr d\theta d\phi$	area = $4\pi a^2$ $dS = r^2 \sin \theta d\theta d\phi$
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Electrostatics

Coulomb's law	$\vec{F}_2 = \frac{Q_1 Q_2}{4\pi\epsilon_0 R^2} \vec{a}_{12}$	$\vec{F} = Q\vec{E}$
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point charge	$\vec{E}(\vec{r}) = \frac{Q(\vec{r} - \vec{r}')}{4\pi\epsilon_0 \vec{r} - \vec{r}' ^3}$	$V(\vec{r}) = \frac{Q}{4\pi\epsilon_0 \vec{r} - \vec{r}' }$
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charge density	$\vec{E}(\vec{r}) = \int_V \frac{\rho_V (\vec{r} - \vec{r}')}{4\pi\epsilon_0 \vec{r} - \vec{r}' ^3} dV'$	$V(\vec{r}) = \int_V \frac{\rho_V}{4\pi\epsilon_0 \vec{r} - \vec{r}' } dV'$
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electric flux	$\Phi = \epsilon_0 \int_S \vec{E} \cdot d\vec{S}$
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Guass's law	$\epsilon_0 \oint_S \vec{E} \cdot d\vec{S} = Q_{\text{encl}} = \int_V \rho_V dV$
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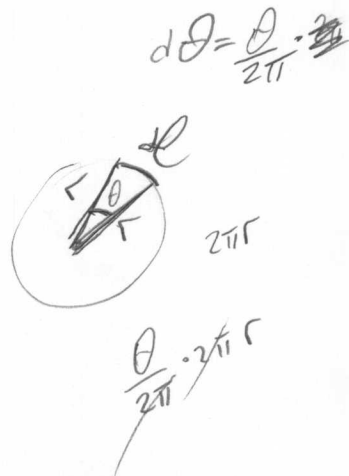
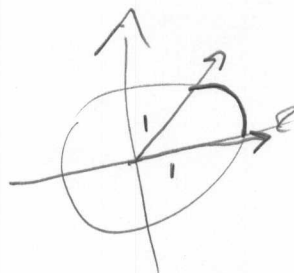
$$\oint \vec{D} \cdot d\vec{S} = Q_{\text{encl}}^{\text{free}} = \int_V \rho_V^{\text{free}} dV$$

$$\oint \vec{P} \cdot d\vec{S} = -Q_{\text{encl}}^{\text{bound}} = -\int_V \rho_V^{\text{bound}} dV$$

relating \vec{E} to V	$\vec{E} = -\vec{\nabla}V$	$V_{AB} = -\int_B^A \vec{E} \cdot d\vec{l}$
capacitance	$C = Q/V$	$C = \frac{\epsilon_0 \epsilon_R A}{d}$ (parallel plate cap.)
linear dielectrics	$\vec{D} = \epsilon_0 \epsilon_R \vec{E}$	
Poisson's equation	$\nabla^2 V = -\rho_V / \epsilon_0 \epsilon_R$	
Laplace's equation	$\nabla^2 V = 0$	
boundary conditions	E_T and D_N continuous across the boundary	
electric field energy	$W_E = \frac{1}{2} \int_V \epsilon_0 \vec{E} ^2 dV$	$W_E = QV$

Magnetostatics

law of Biot-Savart	$\vec{H}(\vec{r}) = \oint \frac{I d\vec{l} \times \vec{a}_R}{4\pi R^2}$	$\vec{H}(\vec{r}) = \int_V \frac{\vec{j} \times \vec{a}_R}{4\pi R^2} dV$
	where \vec{a}_R points from a current element to \vec{r}	
magnetic flux	$\Phi = \mu_0 \int_S \vec{H} \cdot d\vec{S}$	
Ampere's law	$\oint_{\text{loop}} \vec{H} \cdot d\vec{l} = I_{\text{encl}} = \int_S \vec{j} \cdot d\vec{S}$	
vector potential	$\vec{A}(\vec{r}) = \mu_0 \int_V \frac{\vec{j}}{4\pi \vec{r} - \vec{r}' } dV'$	$\vec{B} = \vec{\nabla} \times \vec{A}$
self-inductance	$L = N\Phi/I$ (from linked flux)	$L = \frac{2W_H}{I^2}$ (from energy)
linear materials	$\vec{B} = \mu_0 \mu_R \vec{H}$	
boundary conditions	H_T and B_N continuous across the boundary	
magnetic field energy	$W_H = \frac{1}{2} \int_V \mu_0 \vec{H} ^2 dV$	



Electromagnetics

Maxwell's equations

$$\vec{\nabla} \cdot \vec{D} = \rho_V$$

$$\vec{\nabla} \cdot \vec{B} = 0$$

$$\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

$$\vec{\nabla} \times \vec{H} = \vec{j} + \frac{\partial \vec{D}}{\partial t}$$

Faraday's law

$$\text{emf} = -\frac{d}{dt} \int_S \vec{B} \cdot d\vec{S}$$

EM plane wave

$$\vec{E} = \vec{E}_0 e^{j(\omega t - kz)}$$

$$\vec{H} = \vec{H}_0 e^{j(\omega t - kz)}$$

$$|\vec{H}_0| = |\vec{E}_0| / \eta$$

$$\eta = \sqrt{(\mu_0 \mu_R) / (\epsilon_0 \epsilon_R)}$$

Poynting vector

$$\vec{S} = \Re \vec{E} \times \Re \vec{H}$$

time-averaged \vec{S}

$$\langle \vec{S} \rangle = \frac{|\vec{E}_0|^2}{2\eta}$$

EM wave at a boundary

$$\Gamma = \frac{E_{0r}}{E_{0i}} = \frac{\eta_2 - \eta_1}{\eta_2 + \eta_1}$$

$$\tau = \frac{E_{0t}}{E_{0i}} = \frac{2\eta_2}{\eta_2 + \eta_1} = \Gamma + 1$$

Transmission lines

propagation constant

$$\gamma = \sqrt{(R + j\omega L)(G + j\omega C)} = \alpha + j\beta$$

characteristic impedance

$$Z_0 = \sqrt{(R + j\omega L) / (G + j\omega C)}$$

wavelength and velocity

$$\lambda = 2\pi / \beta$$

$$v_p = \omega / \beta$$

refl. and trans. coeffs.

$$\Gamma = \frac{V_{\text{refl}}}{V_{\text{inc}}} = \frac{Z_L - Z_0}{Z_L + Z_0}$$

$$\tau = \frac{V_{\text{trans}}}{V_{\text{inc}}} = \frac{2Z_L}{Z_L + Z_0} = \Gamma + 1$$

standing wave ratio

$$\text{SWR} = \frac{1 + |\Gamma|}{1 - |\Gamma|}$$

input impedance

$$Z_{\text{in}} = Z_0 \frac{Z_L + jZ_0 \tan(\beta l)}{Z_0 + jZ_L \tan(\beta l)} \quad l \geq 0$$

$$Z_{\text{in}} = Z_0 \frac{1 + \Gamma e^{-j2\beta l}}{1 - \Gamma e^{-j2\beta l}} \quad l \geq 0$$

quarter wave transformer

$$Z_{\text{in}} = Z_Q^2 / Z_L$$

$\Gamma = 0.5$