Symbols and Constants

F	force	V	electric potential
Q	charge	$\vec{A}$	vector potential
$\vec{E}$	electric field	ρ	charge density
$\vec{D}$	displacement field	I	current
$\vec{P}$	polarization field	$\vec{j}$	current density
$\vec{H}$	magnetic field	ε_R	relative permittivity
$\vec{B}$	magnetic flux density field	μ_R	relative permeability
$\vec{M}$	magnetization	$\varepsilon_0 \approx 8.85 \times 10^{-12}$ F/m	
Φ	magnetic flux	$\mu_0 = 4\pi \times 10^{-7}$ N/A^2	

Vector Calculus

cross products:

Cartesian $\quad \vec{a}_x \times \vec{a}_y = \vec{a}_z \quad \vec{a}_y \times \vec{a}_z = \vec{a}_x \quad \vec{a}_z \times \vec{a}_x = \vec{a}_y$

cylindrical $\quad \vec{a}_\rho \times \vec{a}_\phi = \vec{a}_z \quad \vec{a}_\phi \times \vec{a}_z = \vec{a}_\rho \quad \vec{a}_z \times \vec{a}_\rho = \vec{a}_\phi$

spherical $\quad \vec{a}_r \times \vec{a}_\theta = \vec{a}_\phi \quad \vec{a}_\theta \times \vec{a}_\phi = \vec{a}_r \quad \vec{a}_\phi \times \vec{a}_r = \vec{a}_\theta$

volume elements:

Cartesian $\quad dx\,dy\,dz$

cylindrical $\quad \rho d\rho\, d\phi\, dz$

spherical $\quad r^2 \sin\theta dr\, d\theta\, d\phi$

curl (cylindrical)

$$\vec{\nabla} \times \vec{A} = \left[\frac{1}{\rho}\frac{\partial \vec{A}_z}{\partial \phi} - \frac{\partial \vec{A}_\phi}{\partial z}\right]\vec{a}_\rho + \left[\frac{\partial \vec{A}_\rho}{\partial z} - \frac{\partial \vec{A}_z}{\partial \rho}\right]\vec{a}_\phi + \frac{1}{\rho}\left[\frac{\partial(\rho \vec{A}_\phi)}{\partial \rho} - \frac{\partial \vec{A}_\rho}{\partial \phi}\right]\vec{a}_z$$

curl (spherical)

$$\vec{\nabla} \times \vec{A} = \frac{1}{r\sin\theta}\left[\frac{\partial(A_\phi \sin\theta)}{\partial \theta} - \frac{\partial A_\theta}{\partial \phi}\right]\vec{a}_r + \frac{1}{r}\left[\frac{1}{\sin\theta}\frac{\partial A_r}{\partial \phi} - \frac{\partial(rA_\phi)}{\partial r}\right]\vec{a}_\theta + \frac{1}{r}\left[\frac{\partial(rA_\theta)}{\partial r} - \frac{\partial A_r}{\partial \theta}\right]\vec{a}_\phi$$

Electrostatics

Coulomb's law $\quad \vec{F}_2 = \dfrac{Q_1 Q_2}{4\pi\varepsilon_0 R^2}\vec{a}_{12}$

$\vec{E}$ of point charge $\quad \vec{E} = \dfrac{Q\vec{a}_r}{4\pi\varepsilon_0 r^2}$

$\vec{E}$ of charge distribution	$\vec{E} = \int_V \frac{\rho(\vec{r}\,')\,dV'}{4\pi\varepsilon_0 \lvert\vec{r}-\vec{r}\,'\rvert^2} \frac{\vec{r}-\vec{r}\,'}{\lvert\vec{r}-\vec{r}\,'\rvert}$
Gauss's law	$\varepsilon_0 \oint_S \vec{E}\cdot d\vec{S} = Q_{\text{enclosed}}^{\text{total}} = \int_V \rho\, dV$
	$\oint_S \vec{D}\cdot d\vec{S} = Q_{\text{enclosed}}^{\text{free}} = \int_V \rho_{\text{free}}\, dV$
	$\oint_S \vec{P}\cdot d\vec{S} = -Q_{\text{enclosed}}^{\text{bound}} = -\int_V \rho_{\text{bound}}\, dV$
relating $\vec{E}$ to V	$\vec{E} = -\vec{\nabla} V$
relating V to $\vec{E}$	$V_{AB} = -\int_B^A \vec{E}\cdot d\vec{l}$
V of charge distribution	$V = \int_V \frac{\rho(\vec{r}\,')\,dV'}{4\pi\varepsilon_0 \lvert\vec{r}-\vec{r}\,'\rvert}$
capacitance	$C = Q/V$
parallel plate capacitor	$C = \frac{\varepsilon_0\varepsilon_R A}{d}$ of dimensions A and d
Poisson's equation	$\nabla^2 V = -\rho/\varepsilon_0\varepsilon_R$
Laplace's equation	$\nabla^2 V = 0$
linear dielectrics	$\vec{D} = \varepsilon_0\varepsilon_R \vec{E}$
boundary conditions	E_T and D_N continuous
energy	$W = \frac{1}{2}\int_V \vec{E}\cdot\vec{D}\, dV$

Magnetostatics

law of Biot-Savart	$\vec{H} = \oint \frac{I\, d\vec{l} \times \vec{a}_R}{4\pi R^2}$
law of Biot-Savart	$\vec{H} = \int_V \frac{\vec{j} \times \vec{a}_R\, dV}{4\pi R^2}$
Ampere's law	$\oint \vec{H}\cdot d\vec{l} = I_{\text{enclosed}}$
inductance	$L = N\phi/I$
vector potential	$\vec{A} = \int_V \frac{\mu_0 \vec{j}\, dV}{4\pi R}$

relating $\vec{B}$ to $\vec{A}$	$\vec{B} = \vec{\nabla} \times \vec{A}$
linear materials	$\vec{B} = \mu_0 \mu_R \vec{H}$
boundary conditions	H_T and B_N continuous
energy	$W = \frac{1}{2} \int_V \vec{B} \cdot \vec{H}\, dV$

Electromagnetics

Maxwell's equations	$\vec{\nabla} \cdot \vec{D} = \rho$	$\vec{\nabla} \cdot \vec{B} = 0$
	$\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$	$\vec{\nabla} \times \vec{H} = \vec{j} + \frac{\partial \vec{D}}{\partial t}$
Faraday's law	emf $= -d\Phi / dt$	
Poynting vector	$\vec{P} = \mathrm{Re}(\vec{E}) \times \mathrm{Re}(\vec{H})$	

Transmission lines

propagation constant	$\gamma = \sqrt{(R + j\omega L)(G + j\omega C)} = \alpha + j\beta$
characteristic impedance	$Z_0 = \sqrt{(R + j\omega L)/(G + j\omega C)}$
reflection coeff.	$\Gamma = \frac{Z_L - Z_0}{Z_L + Z_0}$
transmission coeff.	$T = \Gamma + 1$
input impedance	$Z_{in} = Z_0 \frac{Z_L + jZ_0 \tan \beta l}{Z_0 + jZ_L \tan \beta l} \qquad l \geq 0$
	$Z_{in} = Z_0 \frac{1 + \Gamma e^{-j2\beta l}}{1 - \Gamma e^{-j2\beta l}} \qquad l \geq 0$
	$\beta = 2\pi / \lambda$
propagation velocity	$v = \omega / \beta$
standing wave ratio	$\mathrm{SWR} = (1 + \lvert\Gamma\rvert)/(1 - \lvert\Gamma\rvert)$