Maxwell's equations:
$$\vec{\nabla}\cdot\vec{D}=\rho_f \qquad \vec{\nabla}\cdot\vec{B}=0 \qquad \vec{D}=\varepsilon\vec{E}$$
$$\vec{\nabla}\times\vec{E}=-\tfrac{\partial\vec{B}}{\partial t} \qquad \vec{\nabla}\times\vec{H}=\vec{J}_f+\tfrac{\partial\vec{E}}{\partial t} \qquad \vec{H}=\tfrac{1}{\mu}\vec{B}$$

Potentials:
$$\vec{B}=\vec{\nabla}\times\vec{A} \text{ and } \vec{E}=-\vec{\nabla}V-\tfrac{\partial\vec{A}}{\partial t} \qquad \vec{A}'=\vec{A}+\vec{\nabla}\lambda \text{ and } V'=V-\tfrac{\partial\lambda}{\partial t}$$
Coulomb: $\vec{\nabla}\cdot\vec{A}=0$ Lorentz: $\vec{\nabla}\cdot\vec{A}=-\tfrac{1}{c^2}\tfrac{\partial V}{\partial t}$

Wave equation: $\nabla^2\psi(\vec{r},t)=\dfrac{1}{v^2}\dfrac{\partial^2\psi(\vec{r},t)}{\partial t^2}$ Wave velocities: $v_p=\dfrac{\omega}{k},\ v_g=\dfrac{d\omega}{dk}$

Plane wave: $\vec{E}(\vec{r},t)=\tilde{\vec{E}}_0 e^{i(\vec{k}\cdot\vec{r}-\omega t)} \qquad \tilde{\vec{E}}_0\cdot\vec{k}=0 \qquad \omega\tilde{\vec{B}}_0=\vec{k}\times\tilde{\vec{E}}_0$

Poynting vector: $\vec{S}=\vec{E}\times\vec{H}$

Field energy: $U=\dfrac{1}{2}\vec{E}\cdot\vec{D}+\dfrac{1}{2}\vec{B}\cdot\vec{H}$

Stress tensor: $T_{ij}=(E_iD_j-\tfrac{1}{2}\delta_{ij}\vec{E}\cdot\vec{D})+(B_iH_j-\tfrac{1}{2}\delta_{ij}\vec{B}\cdot\vec{H})$

Force density: $\vec{f}=\vec{\nabla}\cdot\vec{T}-\varepsilon\mu\dfrac{\partial\vec{S}}{\partial t}$

Continuity equation: $\vec{\nabla}\cdot\vec{j}=-\tfrac{\partial\rho}{\partial t}$ Impedance: $Z=\tfrac{V}{I}$ Snell's Law: $\tfrac{\sin\theta_t}{\sin\theta_i}=\tfrac{n_i}{n_t}$

Boundary conditions: $\varepsilon_1E_{1\perp}-\varepsilon_2E_{2\perp}=\sigma_f$; $B_{1\perp}=B_{2\perp}$; $E_{1\parallel}=E_{2\parallel}$; $\tfrac{1}{\mu_1}B_{1\parallel}-\tfrac{1}{\mu_2}B_{2\parallel}=K_f$

Normal incidence on dielectric:
$$T\equiv\frac{I_t}{I_i}=\frac{\varepsilon_2v_2}{\varepsilon_1v_1}\left(\frac{E_t^2}{E_i^2}\right)=\frac{4n_1n_2}{(n_1+n_2)^2}$$
$$R\equiv\frac{I_r}{I_i}=\left(\frac{E_r^2}{E_i^2}\right)=\frac{(n_1-n_2)^2}{(n_1+n_2)^2}$$

Cavity: $\omega=c\left[\left(\tfrac{m\pi}{a}\right)^2+\left(\tfrac{n\pi}{b}\right)^2+\left(\tfrac{l\pi}{d}\right)^2\right]^{\frac{1}{2}}$

Electric dipole radiation:
$$\vec{E}(\vec{r},t)=\frac{\mu_0}{4\pi r}\left(\hat{r}\times\left(\hat{r}\times\ddot{\vec{p}}\right)\right)=\frac{\mu_0\ddot{p}}{4\pi}\left(\frac{\sin\theta}{r}\right)\hat{\theta} \qquad \vec{B}(\vec{r},t)=\frac{\hat{r}\times\vec{E}}{c}$$
$$\langle\vec{S}\rangle=\left(\frac{\mu_0p_0^2\omega^4}{32\pi^2c}\right)\frac{\sin^2\theta}{r^2}\hat{r} \qquad P=\frac{\mu_0p_0^2\omega^4}{12\pi c}$$

Radiation from a point charge: $\vec{E}=\dfrac{q}{4\pi\varepsilon_0\left(\vec{\mathscr{r}}\cdot\vec{u}\right)^3}\left(\vec{\mathscr{r}}\times\left(\vec{u}\times\vec{a}\right)\right)$, where $\vec{u}=c\hat{\mathscr{r}}-\vec{v}$. $P=\dfrac{\mu_0q^2a^2}{6\pi c}$

Lorentz transformation: $\begin{pmatrix}\gamma & -\beta\gamma\\ -\beta\gamma & \gamma\end{pmatrix}$ $\quad v'=\dfrac{v+v_R}{1+\frac{vv_R}{c^2}}$

4-vectors: $x^\mu=\left(ct,\vec{r}\right)\quad j^\mu=\left(c\rho,\vec{j}\right)$
$A^\mu=\left(\tfrac{V}{c},\vec{A}\right)\quad k^\mu=\left(\tfrac{\omega}{c},\vec{k}\right)$

Field tensor: $F^{\mu\nu} = \begin{pmatrix} 0 & \frac{E_x}{c} & \frac{E_y}{c} & \frac{E_z}{c} \\ -\frac{E_x}{c} & 0 & B_z & -B_y \\ -\frac{E_y}{c} & -B_z & 0 & B_x \\ -\frac{E_z}{c} & B_y & -B_x & 0 \end{pmatrix} = \partial^\mu A^\nu - \partial^\nu A^\mu$

Maxwell's equations:
$$\begin{aligned} &\partial_\nu F^{\mu\nu} = \mu_0 j^\mu \\ &\partial_\nu G^{\mu\nu} = 0 \\ &\Box^2 A^\mu = -\mu_0 j^\mu \end{aligned}$$

<u>Math:</u>

Fourier analysis: $\tilde{f}(z,t) = \int_{-\infty}^{+\infty} \tilde{A}(k) e^{i(kz-\omega t)} dk \qquad \tilde{A}(k) = \frac{1}{2\pi} \int_{-\infty}^{+\infty} \left[f(z,0) + \frac{i}{\omega} \frac{\partial f(z,0)}{\partial t} \right] e^{-ikz} dz$

$$e^{i\theta} = \cos\theta + i\sin\theta \qquad \int_{-\infty}^{\infty} e^{-(z+ik)^2} dz = \sqrt{\pi}$$

$$\vec{\nabla}\times(f\vec{A}) = f(\vec{\nabla}\times\vec{A}) - \vec{A}\times(\vec{\nabla}f) \qquad \vec{\nabla}\cdot(\vec{A}\times\vec{B}) = \vec{B}\cdot(\vec{\nabla}\times\vec{A}) - \vec{A}\cdot(\vec{\nabla}\times\vec{B})$$

$$\vec{\nabla}\times(\vec{\nabla}\times\vec{A}) = \vec{\nabla}(\vec{\nabla}\cdot\vec{A}) - \nabla^2\vec{A} \qquad \vec{\nabla}\times(\vec{A}\times\vec{B}) = (\vec{B}\cdot\vec{\nabla})\vec{A} - (\vec{A}\cdot\vec{\nabla})\vec{B} + \vec{A}(\vec{\nabla}\cdot\vec{B}) - \vec{B}(\vec{\nabla}\cdot\vec{A})$$

Spherical unit vectors:

$$\hat{r} = \sin\theta\cos\phi\hat{x} + \sin\theta\sin\phi\hat{y} + \cos\theta\hat{z}$$
$$\hat{\theta} = \cos\theta\cos\phi\hat{x} + \cos\theta\sin\phi\hat{y} - \sin\theta\hat{z}$$
$$\hat{\phi} = -\sin\phi\hat{x} + \cos\phi\hat{y}$$

Cylindrical unit vectors:

$$\hat{s} = \cos\phi\hat{x} + \sin\phi\hat{y}$$
$$\hat{\phi} = -\sin\phi\hat{x} + \cos\phi\hat{y}$$

$\vec{\nabla}A = \frac{\partial A}{\partial x}\hat{x} + \frac{\partial A}{\partial y}\hat{y} + \frac{\partial A}{\partial z}\hat{z}$	$\vec{\nabla}\cdot\vec{v} = \frac{\partial v_x}{\partial x} + \frac{\partial v_y}{\partial y} + \frac{\partial v_z}{\partial z}$	Cartesian
$\vec{\nabla}A = \frac{\partial A}{\partial r}\hat{r} + \frac{1}{r}\frac{\partial A}{\partial \theta}\hat{\theta} + \frac{1}{r\sin\theta}\frac{\partial A}{\partial \phi}\hat{\phi}$	$\vec{\nabla}\cdot\vec{v} = \frac{1}{r^2}\frac{\partial}{\partial r}(r^2 v_r) + \frac{1}{r\sin\theta}\frac{\partial}{\partial\theta}(\sin\theta\, v_\theta) + \frac{1}{r\sin\theta}\frac{\partial v_\phi}{\partial\phi}$	Spherical
$\vec{\nabla}A = \frac{\partial A}{\partial s}\hat{s} + \frac{1}{s}\frac{\partial A}{\partial \phi}\hat{\phi} + \frac{\partial A}{\partial z}\hat{z}$	$\vec{\nabla}\cdot\vec{v} = \frac{1}{s}\frac{\partial}{\partial s}(s v_s) + \frac{1}{s}\frac{\partial v_\phi}{\partial\phi} + \frac{\partial v_z}{\partial z}$	Cylindrical