Physics 401 Unofficial Formula Sheet

Constants

Electric Constant	$\epsilon_0 = 8.854 \times 10^{-12}\,\frac{\mathrm{C}^2}{\mathrm{Nm}^2}$
Elementary Charge	$e = 1.602 \times 10^{-19}\,\mathrm{C}$
Vacuum Permeability	$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{N/A}^2$
Speed of Light	$c = \frac{1}{\sqrt{\epsilon_0\mu_0}} = 2.998 \times 10^8\,\mathrm{m/s}$

Phys 301 Review

Maxwell's Equations

$$\nabla \cdot \vec{E} = \frac{\rho}{\epsilon_0} \qquad \nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

$$\nabla \cdot \vec{B} = 0 \qquad \nabla \times \vec{B} = \mu_0 \vec{J} + \mu_0\epsilon_0 \frac{\partial \vec{E}}{\partial t}$$

$$\oiint \vec{E} \cdot d\vec{a} = \frac{Q_{\mathrm{enc}}}{\epsilon_0} \qquad \oint \vec{E} \cdot d\vec{l} = -\frac{d\Phi_B}{dt}$$

$$\oiint \vec{B} \cdot d\vec{a} = 0 \qquad \oint \vec{B} \cdot d\vec{l} = \mu_0 I_{\mathrm{enc}} + \mu_0\epsilon_0 \frac{d\Phi_E}{dt}$$

Linear Media

Dielectric constant	$\epsilon = \epsilon_r \epsilon_0$

Chapter 8

8.1.1 Continuity Equation

Continuity Equation	$\frac{\partial \rho}{\partial t} = -\vec{\nabla} \cdot \vec{J}$

8.1.2 Poynting's Theorem

Total energy	$W = \iiint u\,d\tau$
Energy density	$u = \frac{1}{2}\left(\epsilon_0 E^2 + \frac{1}{\mu_0} B^2\right)$
Poynting vector	$\vec{S} = \frac{1}{\mu_0}\left(\vec{E} \times \vec{B}\right)$
Energy continuity	$\frac{\partial u}{\partial t} = -\nabla \cdot \vec{S}$
Power	$P = \frac{dW}{dt} = -\oiint \vec{S} \cdot d\vec{a}$

8.2.3 Conservation of Momentum

Momentum	$\vec{p} = \iiint \vec{g}\,d\tau$
Momentum density	$\vec{g} = \mu_0\epsilon_0 \vec{S} = \epsilon_0\left(\vec{E} \times \vec{B}\right)$
Angular momentum	$\vec{L} = \iiint \vec{l}\,d\tau$
Angular momentum density	$\vec{l} = \vec{r} \times \vec{g}$
Torque	$\vec{N} = \vec{r} \times \vec{F}$

8.2.4 Angular Momentum

Angular momentum	$\vec{L} = \iiint \vec{l}\,d\tau$
Angular momentum density	$\vec{l} = \vec{r} \times \vec{g} = \epsilon_0\left(\vec{r} \times (\vec{E} \times \vec{B})\right)$
Torque	$\vec{N} = \vec{r} \times \vec{F}$

Chapter 9: Wave Incidence and Propogation

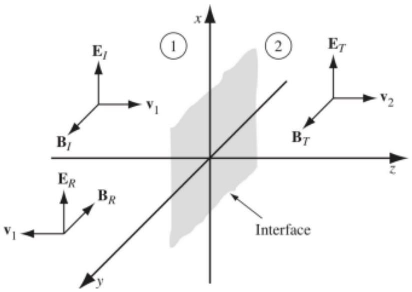
Boundary Conditions

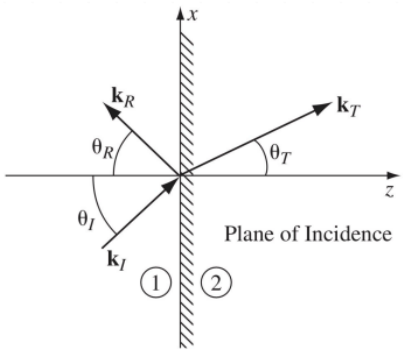
$\epsilon_1 \vec{E}_1^{\perp} = \epsilon_2 \vec{E}_2^{\perp}$ $\qquad$ $\vec{E}_1^{\parallel} = \vec{E}_2^{\parallel}$

$\vec{B}_1^{\perp} = \vec{B}_2^{\perp}$ $\qquad$ $\dfrac{\vec{B}_1^{\parallel}}{\mu_1} = \dfrac{\vec{B}_2^{\parallel}}{\mu_2}$

$E_{0I} + E_{0R} = E_{0T}$ $\qquad$ $B_{0I} - B_{0R} = B_{0T} \Rightarrow \dfrac{1}{\mu_1 v_1}(E_{0I} - E_{0R}) = \dfrac{E_{0T}}{\mu_2 v_2}$

Incidence Diagrams





Electromagnetic Waves

Wave speed $\qquad v = \dfrac{1}{\sqrt{\mu\epsilon}} = \dfrac{\omega}{k} = \dfrac{c}{n}$

Index of refraction $\qquad n = \frac{c}{v} = \sqrt{\frac{\epsilon\mu}{\epsilon_0\mu_0}} \approx \sqrt{\epsilon_r}$

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

Electric field $\qquad \vec{E} = E_0 e^{i(\vec{k}\cdot\vec{r}-\omega t)}\hat{n}$

Magnetic field $\qquad \vec{B} = \dfrac{\vec{k}\times\vec{E}}{\omega}$

Propagation

Reflected $\qquad \dfrac{E_{0R}}{E_{0I}} = \left(\dfrac{\alpha-\beta}{\alpha+\beta}\right), \quad R = \left(\dfrac{\alpha-\beta}{\alpha+\beta}\right)^2$

Transmitted $\qquad \dfrac{E_{0T}}{E_{0I}} = \dfrac{2}{\alpha+\beta}, \quad T = \dfrac{4\alpha\beta}{(\alpha+\beta)^2}$

Conservation of energy $\qquad$ R+T=1

Alpha $\qquad \alpha = \dfrac{\cos\theta_T}{\cos\theta_I}$

Beta $\qquad \beta = \dfrac{\mu_1 v_1}{\mu_2 v_2} = \dfrac{\mu_1 n_2}{\mu_2 n_1}$

Reflection and refraction $\qquad \theta_I = \theta_R, \quad \dfrac{\sin\theta_T}{\sin\theta_I} = \dfrac{n_1}{n_2}$

Brewster's angle ($\vec{E}_R = \vec{0}$) $\qquad \alpha = \beta:\ \sin^2\theta_B = \frac{1-\beta^2}{\left(\frac{n_1}{n_2}\right)^2-\beta^2}$

Chapter 9: Guided Waves

Propagation in a Conductor

Current density $\qquad \vec{J}_f = \sigma\vec{E}$ (where σ is conductivity)

Characteristic time $\qquad \tau = \dfrac{\epsilon}{\sigma}$

Wave number $\qquad \tilde{k} = k_1 + k_2, \quad \begin{cases} k_1 = \omega\sqrt{\frac{\epsilon\mu}{2}}\left(\sqrt{1+\left(\frac{\sigma}{\epsilon\omega}\right)^2}+1\right)^{1/2} \\ k_2 = \omega\sqrt{\frac{\epsilon\mu}{2}}\left(\sqrt{1+\left(\frac{\sigma}{\epsilon\omega}\right)^2}-1\right)^{1/2} \end{cases}$

Fields $\qquad \begin{cases} \vec{E}(z,t) = E_0 e^{-k_2 z}\cos(k_1 z - \omega t + \delta_E)\hat{x} \\ \vec{B}(z,t) = B_0 e^{-k_2 z}\cos(k_1 z - \omega t + \delta_E + \phi)\hat{y} \end{cases}$

Phase shift $\qquad \tan(\phi) = \dfrac{k_2}{k_1}$

Amplitude relationship $\qquad \dfrac{B_0}{E_0} = \dfrac{|\tilde{k}|}{\omega} = \dfrac{\sqrt{k_1^2+k_2^2}}{\omega} = \sqrt{\epsilon\mu\sqrt{1+\left(\dfrac{\sigma}{\epsilon\omega}\right)^2}}$

Rectangular Wave Guide (TE or TM Waves)

TE Waves $\qquad E_z = 0, \quad B_z = B_0\cos\left(\dfrac{m\pi x}{a}\right)\cos\left(\dfrac{n\pi y}{b}\right)$

TM Waves $\qquad B_z = 0$

E-field $\qquad E_x = \frac{i}{\left(\frac{\omega}{c}\right)^2-k^2}\left(k\dfrac{\partial E_z}{\partial x} + \omega\dfrac{\partial B_z}{\partial y}\right), \quad E_y = \frac{i}{\left(\frac{\omega}{c}\right)^2-k^2}\left(k\dfrac{\partial E_z}{\partial y} - \omega\dfrac{\partial B_z}{\partial x}\right)$

B-field $\qquad E_x = \frac{i}{\left(\frac{\omega}{c}\right)^2-k^2}\left(k\dfrac{\partial E_z}{\partial x} - \dfrac{\omega}{c^2}\dfrac{\partial B_z}{\partial y}\right), \quad E_y = \frac{i}{\left(\frac{\omega}{c}\right)^2-k^2}\left(k\dfrac{\partial E_z}{\partial y} + \dfrac{\omega}{c^2}\dfrac{\partial B_z}{\partial x}\right)$

Cut-off frequency $\qquad \omega_{mn} = c\pi\sqrt{\left(\dfrac{m}{a}\right)^2 + \left(\dfrac{n}{b}\right)^2}$

Wave number $\qquad k = \dfrac{1}{c}\sqrt{\omega^2 - \omega_{mn}^2}$

Wave velocity $\qquad v = \dfrac{\omega}{k} = \dfrac{c}{\sqrt{1-\left(\frac{\omega_{mn}}{\omega}\right)^2}} > c$

Group velocity $\qquad v_g = \dfrac{1}{\frac{dk}{d\omega}} = c\sqrt{1-\left(\dfrac{\omega_{mn}}{\omega}\right)^2} < c$

Coaxial Transmission Line (TEM Waves)

Fields $\qquad \vec{E} = \dfrac{A\cos(kz-\omega t)}{s}\hat{s}, \quad \vec{B} = \dfrac{A\cos(kz-\omega t)}{cs}\hat{\phi}$

Chapter 10

Potentials

Electric Field $\vec{E} = -\vec{\nabla} V - \dfrac{\partial \vec{A}}{\partial t}$

Magnetic Field $\vec{B} = \vec{\nabla} \times \vec{A}$

Maxwell's Eqns $\begin{cases} \nabla^2 V + \frac{\partial}{\partial t}(\vec{\nabla}\cdot\vec{A}) = -\frac{1}{\epsilon_0}\rho \\ \nabla^2\vec{A} - \mu_0\epsilon_0\frac{\partial^2\vec{A}}{\partial t^2} - \vec{\nabla}(\vec{\nabla}\cdot\vec{A} + \mu_0\epsilon_0\frac{\partial V}{\partial t}) = -\mu_0\vec{J} \end{cases}$

Gauge Freedom $\begin{cases} \vec{A}' = \vec{A} + \vec{\nabla}\lambda \\ V' = V - \frac{\partial\lambda}{\partial t} \end{cases}, \quad \lambda = f(\vec{r}, t)$

Coulomb Gauge $\vec{\nabla}\cdot\vec{A} = 0, \quad \begin{cases} \nabla^2 V = -\frac{1}{\epsilon_0}\rho \\ \nabla^2\vec{A} - \mu_0\epsilon_0\frac{\partial^2\vec{A}}{\partial t^2} = -\mu_0\vec{J} + \mu_0\epsilon_0\vec{\nabla}(\frac{\partial V}{\partial t}) \end{cases}$

Lorentz Gauge $\vec{\nabla}\cdot\vec{A} = -\mu_0\epsilon_0\frac{\partial V}{\partial t}, \quad \begin{cases} \nabla^2 V - \mu_0\epsilon_0\frac{\partial^2 V}{\partial t^2} = -\frac{1}{\epsilon_0}\rho \\ \nabla^2\vec{A} - \mu_0\epsilon_0\frac{\partial^2\vec{A}}{\partial t^2} = -\mu_0\vec{J} \end{cases}$

d'Alembertian Operator $\Box^2 = \nabla^2 - \mu_0\epsilon_0\frac{\partial^2}{\partial t^2}$

Lorentz force $\vec{F} = q\left(-\nabla V - \dfrac{\partial\vec{A}}{\partial t} + \vec{v}\times(\nabla\times\vec{A})\right)$

Total Derivative of $\vec{A}$ $\frac{d\vec{A}}{dt} = \frac{\partial\vec{A}}{\partial t} + (\vec{v}\cdot\vec{\nabla})\vec{A}$

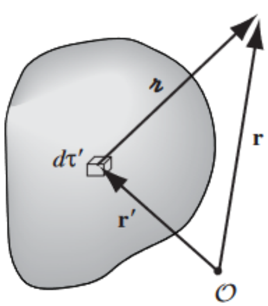
Canonical Momentum $\vec{p}_{\text{can}} = \vec{p} + q\vec{A}$

Potential Energy $U_{\text{vel}} = q(V - \vec{v}\cdot\vec{A})$

Retarded potentials

Retarded time $t_r = t - \frac{\mathscr{r}}{c}$

Potentials $V(\vec{r}, t) = \dfrac{1}{4\pi\epsilon_0}\displaystyle\int \frac{\rho(\vec{r}', t_r)}{\mathscr{r}} d\tau', \quad \vec{A}(\vec{r}, t) = \frac{\mu_0}{4\pi}\int\frac{\vec{J}(\vec{r}', t_r)}{\mathscr{r}} d\tau'$



Moving Point Charges

$\vec{w}(t)$ position of q at time t

Retarded time $\mathscr{r} = \lvert\vec{r} - \vec{w}(t_r)\rvert = c(t - t_r)$

Potential $V(\vec{r}, t) = \dfrac{1}{4\pi\epsilon_0}\dfrac{qc}{(\mathscr{r}c - \vec{\mathscr{r}}\cdot\vec{v})}$

Vector potential $\vec{A}(\vec{r}, t) = \dfrac{\vec{v}}{c^2}V(\vec{r}, t)$

$\vec{u}$ vector $\vec{u} = c\hat{\mathscr{r}} - \vec{v}$

Electric field $\vec{E}(\vec{r}, t) = \dfrac{q}{4\pi\epsilon_0}\dfrac{\mathscr{r}}{(\vec{\mathscr{r}}\cdot\vec{u})^3}\left((c^2 - v^2)\vec{u} + \vec{\mathscr{r}}\times(\vec{u}\times\vec{a})\right)$

Magnetic field $\vec{B}(\vec{r}, t) = \dfrac{1}{c}\hat{\mathscr{r}}\times\vec{E}(\vec{r}, t)$

Chapter 11: Radiation

WTF is Radiation

Power $P(r, t) = \oint\!\!\oint \vec{S}\cdot d\vec{a} = \dfrac{1}{\mu_0}\oint(\vec{E}\times\vec{B})\cdot d\vec{a}$

Radiative Power $P_{rad}(t_0) = \lim\limits_{r\to\infty} P(r, t - \frac{r}{c})$

Electric Dipole Radiation

Source $q(t) = q_0\cos(\omega t), \quad \vec{p}(t) = p_0\cos(\omega t)\hat{z}, \quad p_o \equiv q_0 d$

Approximations $1)\ 0 < d \ll r, \quad 2)\ d \ll \dfrac{c}{\omega}, \quad 3\ r \gg \dfrac{c}{\omega}$

Potential $V(r, \theta, t) = -\dfrac{p_0\omega}{4\pi\epsilon_0 c}\left(\dfrac{\cos\theta}{r}\right)\sin\left(\omega(t - \frac{r}{c})\right), \quad \cos\theta = \dfrac{\vec{p}\cdot\hat{\mathscr{r}}}{p_0}$

Current $I(t) = \frac{dq}{dt}\hat{z} = -q_0\omega\sin\omega t\hat{z}$

Vector potential $\vec{A}(r, \theta, t) = -\dfrac{\mu_0 p_0\omega}{4\pi r}\sin\left(\omega(t - \frac{r}{c})\right)\hat{z}$

Electric field $\vec{E} = -\dfrac{\mu_0 p_0\omega^2}{4\pi}\left(\dfrac{\sin\theta}{r}\right)\cos\left(\omega(t - \frac{r}{c})\right)\hat{\theta}$

Magnetic field $\vec{B} = -\dfrac{\mu_0 p_0\omega^2}{4\pi c}\left(\dfrac{\sin\theta}{r}\right)\cos\left(\omega(t - \frac{r}{c})\right)\hat{\phi} = \dfrac{1}{c}(\hat{r}\times\vec{E})$

Poynting Vector $\vec{S}(\vec{r}, t) = \dfrac{\mu_0}{c}\left(\dfrac{p_0\omega^2}{4\pi}\left(\dfrac{\sin\theta}{r}\right)\cos\left(\omega\left(t - \dfrac{r}{c}\right)\right)\right)^2\hat{r}$

Intensity $I = \left\langle\vec{S}\right\rangle = \dfrac{\mu_0 p_0^2\omega^4}{32\pi^2 c}\dfrac{\sin^2\theta}{r^2}\hat{r}$

Total Radiated Power $\langle P\rangle = \displaystyle\int\left\langle\vec{S}\right\rangle\cdot d\vec{a} = \frac{\mu_0 p_0^2\omega^4}{12\pi c}$

Magnetic Dipole Radiation

Source $I(t) = I_0\cos(\omega t), \quad \vec{m}(t) = m_0\cos(\omega t)\hat{z}$

Vector potential $\vec{A}(r, \theta, t) = -\dfrac{\mu_0 m_0\omega}{4\pi c}\left(\dfrac{\sin\theta}{r}\right)\sin\left(\omega(t - \frac{r}{c})\right)\hat{\phi}$

Electric field $\vec{E} = \dfrac{\mu_0 m_0\omega^2}{4\pi c}\left(\dfrac{\sin\theta}{r}\right)\cos\left(\omega(t - \frac{r}{c})\right)\hat{\phi}$

Magnetic field $\vec{B} = -\dfrac{\mu_0 m_0\omega^2}{4\pi c^2}\left(\dfrac{\sin\theta}{r}\right)\cos\left(\omega(t - \frac{r}{c})\right)\hat{\theta}$

General Electric Dipole Radiation

Potential $V(\vec{r}, t) \cong \dfrac{1}{4\pi\epsilon_0}\left(\dfrac{Q}{r} + \dfrac{\hat{r}\cdot\vec{p}(t_0)}{r^2} + \dfrac{\hat{r}\cdot\dot{p}_0(t_0)}{rc}\right)$

Vector Potential $\vec{A}(\vec{r}, t) \cong \dfrac{\mu_0}{4\pi}\dfrac{\dot{\vec{p}}(t_0)}{r}$

Electric field $\vec{E}(\vec{r}, t) = \dfrac{\mu_0}{4\pi r}\left(\hat{r}\times(\hat{r}\times\ddot{\vec{p}})\right)$

Magnetic field $\vec{B}(\vec{r}, t) = -\dfrac{\mu_0}{4\pi rc}(\hat{r}\times\ddot{\vec{p}})$

Poynting vector $\vec{S} = \dfrac{\mu_0}{16\pi^2 r^2 c}[\ddot{\vec{p}}^2 - (\hat{r}\cdot\ddot{\vec{p}})^2]\hat{r} = \dfrac{\mu_0}{16\pi^2 c}\lvert\ddot{\vec{p}}\rvert^2\left(\dfrac{\sin^2\theta}{r^2}\right)\hat{r} = \dfrac{E_{\text{rad}}^2}{\mu_0 c}\hat{r}$

Larmor formula $P = \dfrac{\mu_0 q^2 a^2}{6\pi c}, \quad v \ll c$ (Non-relativistic)

Radiation force $\vec{F}_{\text{rad}} = \dfrac{\mu_0 q^2}{6\pi c}\dot{\vec{a}}, \quad \begin{cases}\text{Time average and only when} \\ \text{system returns to initial state}\end{cases}$

Use in EoM $\vec{F}_{rad} = m\tau\dddot{x}, \quad \tau \equiv \frac{\mu_0 q^2}{6\pi mc}$

Chapter 12: Relativistic Electrodynamics

Relativity?!?

Lorentz Factor	$\gamma = \dfrac{1}{\sqrt{1 - v^2/c^2}}$
Beta Ratio	$\beta = \dfrac{v}{c}$
Time Dilation	$\Delta\bar{t} = \frac{1}{\gamma}\Delta t$
Lorentz Contraction	$\Delta\bar{x} = \gamma\Delta x$
Lorentz Transformations	$\begin{cases} \bar{x} = \gamma(x - vt) \\ \bar{y} = y \\ \bar{z} = z \\ \bar{t} = \gamma(t - \frac{v}{c^2}x) \end{cases} \quad \begin{cases} x = \gamma(\bar{x} + v\bar{t}) \\ y = \bar{y} \\ z = \bar{z} \\ t = \gamma(\bar{t} + \frac{v}{c^2}\bar{x}) \end{cases}$
Lorentz Tranformation Matrix	$\Lambda = \begin{bmatrix} \gamma & -\gamma\beta & 0 & 0 \\ -\gamma\beta & \gamma & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$
Lorentz Gauge Condition	$\frac{1}{c^2}\frac{\partial V}{\partial t} + \vec{\nabla}\cdot\vec{A} = 0$
Proper Time	$d\tau = \sqrt{1 - u^2/c^2}dt$
Proper Velocity	$\vec{\eta} = \dfrac{d\vec{l}}{d\tau} = \dfrac{1}{\sqrt{1 - u^2/c^2}}\vec{u}, \quad \bar{\eta}^\mu = \Lambda^\mu_\nu \eta^\nu$
Momentum	$\vec{p} = m\vec{\eta}, \quad p^\mu = m\eta^\mu$
Energy	$E = p^0 c = \dfrac{mc^2}{\sqrt{1 - u^2/c^2}}$
	$E^2 - p^2c^2 = m^2c^4$
Wave number	$\bar{k} = \gamma\left(k - \frac{v\omega}{c^2}\right), \quad \bar{\omega} = \gamma(\omega - kv)$
Red/blue shift	$\begin{cases} \text{red shift if } \bar{\omega} < \omega \\ \text{blue shift if } \bar{\omega} > \omega \end{cases}$

Relativistic Fields

Electric Field	$\overline{E_x} = E_x, \overline{E_y} = \gamma(E_y - vB_z), \overline{E_z} = \gamma(E_z + vB_y)$
Magnetic Field	$\overline{B_x} = B_x, \overline{B_y} = \gamma(B_y + \frac{v}{c^2}E_z), \overline{B_z} = \gamma(B_z - \frac{v}{c^2}E_y)$
If $\vec{B} = 0$	$\vec{\bar{B}} = -\frac{1}{c^2}(\vec{v}\times\vec{\bar{E}})$
If $\vec{E} = 0$	$\vec{\bar{E}} = \vec{v}\times\vec{\bar{B}}$

Common Four-Vectors

Position	$x^\mu = (ct, \vec{x})$	Velocity	$\eta^\mu = \left(\frac{E}{mc}, \vec{v}\right)$
Momentum	$p^\mu = \left(\frac{E}{c}, \vec{p}\right)$	Wave number	$k^\mu = \left(\frac{\omega}{c}, \vec{k}\right)$
Current density	$J^\mu = \left(c\rho, \vec{J}\right)$	Potential	$A^\mu = \left(\frac{V}{c}, \vec{A}\right)$
Force	$f^\mu = \left(\dfrac{\vec{F}\cdot\frac{\vec{v}}{c}}{\sqrt{1 - \frac{v^2}{c^2}}}, \dfrac{\vec{F}}{\sqrt{1 - \frac{v^2}{c^2}}}\right),$		$\vec{F} = \dfrac{d\vec{p}}{dt}$
4 Force EoM	$m_0\dfrac{d^2x^\mu}{ds^2} = f^\mu = qu^\nu F^{\mu\nu}$		
Example	$f^x = q(u^t F^{xt} - u^y F^{xy} - u^z F^{xz})$		

Chapter 12: More Relativity

Tensors

Field Tensor	$F^{\mu\nu} = \begin{Bmatrix} 0 & E_x/c & E_y/c & E_Z/c \\ -E_x/c & 0 & B_z & -B_y \\ -E_y/c & -B_z & 0 & B_x \\ -E_z/c & B_y & -B_x & 0 \end{Bmatrix}$
Dual Tensor	$G^{\mu\nu} = \begin{Bmatrix} 0 & B_x & B_y & B_z \\ -B_x & 0 & -E_z/c & E_y/c \\ -B_y & E_z/c & 0 & -E_x/c \\ -B_z & -E_y/c & E_x/c & 0 \end{Bmatrix}$
Current Density	$\vec{J} = \rho\vec{u}$, $\rho = \frac{Q}{V}$, Q = charge, V = volume
4-Current Density	$\begin{cases} J^\mu = (c\rho, J_x, J_y, J_z) \\ \frac{\partial J^\mu}{\partial x^\mu} = 0 \end{cases}$
Maxwell's Equations	$\dfrac{\partial F^{\mu\nu}}{\partial x^\nu} = \mu_0 J^\mu, \quad \dfrac{\partial G^{\mu\nu}}{\partial x^\nu} = 0$
Minkowski Force	$K^\mu = q\eta_\nu F^{\mu\nu}$, η = proper velocity

Relativistic Potentials

Vector Potential	$A^\mu = (V/c, A_x, A_y, A_z)$
Field Tensor	$F^{\mu\nu} = \dfrac{\partial A^\nu}{\partial x_\mu} - \dfrac{\partial A^\mu}{\partial x_\nu}$
Lorentz Gauge	$\Box^2 A^\mu = -\mu_0 J^\mu$

Relativistic Fields of a Point Charge with a Constant Velocity

Scalar Potential	$V = \dfrac{q}{4\pi\epsilon_0}\dfrac{1}{\sqrt{(x-ut)^2 + (1 - u^2/c^2)(y^2+z^2)}}$
Vector Potential	$A = \dfrac{u}{c^2}\dfrac{q}{4\pi\epsilon_0}\dfrac{1}{\sqrt{(x-ut)^2 + (1 - u^2/c^2)(y^2+z^2)}}(1,0,0)$
Electric Field	$E = \dfrac{q}{4\pi\epsilon_0}\dfrac{1}{\sqrt{1 - u^2/c^2}}\dfrac{1}{\left[\frac{(x-ut)^2}{1-u^2/c^2} + y^2 + z^2\right]^{3/2}}\langle x - ut, y, z\rangle$
Magnetic Field	$\vec{B} = \dfrac{\vec{u}}{c^2}\times\vec{E}$
	$B_z = \dfrac{u}{c^2}E_y,\ B_y = -\dfrac{u}{c^2}E_z,\ B_x = 0$

Four Vectors

Vector	$A^\mu = (A_t, A_x, A_y, A_z) = (A_t, \vec{A})$
Scalar Product	$A^\mu B^\mu = A_t B_t - \vec{A}\cdot\vec{B}$
Vector Operator	$\nabla^\mu = (\partial/\partial t, -\vec{\nabla})$
Gradient	$\nabla^\mu\phi = (\frac{\partial\phi}{\partial t}, -\vec{\nabla}\phi)$
Divergence	$\nabla^\mu A^\mu = \frac{\partial A_t}{\partial t} + \vec{\nabla}\vec{A}$
Laplacian and d'Alembertian	$\nabla^\mu\nabla^\mu = \frac{\partial^2}{\partial t^2} - \nabla^2 = \Box^2$