

$\nabla \cdot \mathbf{D} = \rho_f, \quad \nabla \times \mathbf{E} = 0, \quad \nabla \cdot \mathbf{B} = 0, \quad \nabla \times \mathbf{H} = \mathbf{J}_f$	Maxwell's equations in matter	$\mathbf{H} = \frac{1}{\mu_0} \mathbf{B} - \mathbf{M}$	Magnetic field (5.81)
$\mathbf{E}(\mathbf{x}) = \frac{1}{4\pi\epsilon_0} \int \rho(\mathbf{x}') \frac{\mathbf{x} - \mathbf{x}'}{ \mathbf{x} - \mathbf{x}' ^3} d^3x'$	Coulomb's Law (1.5)	$\mathbf{M} = (\mu/\mu_0 - 1)\mathbf{H}$	Magnetization in linear media (G. 6.29)
$\delta(f(x)) = \sum_i \left[\frac{1}{\left \frac{df}{dx}(x_i) \right } \delta(x - x_i) \right]$	Delta function Rule 5	$\mathbf{B} = \mu \mathbf{H}$	Linear condition (5.84)
$\oint_S \mathbf{E} \cdot \mathbf{n} \, da = \frac{1}{\epsilon_0} \int_V \rho(\mathbf{x}) d^3x$	Gauss' Law (1.11)	$\begin{cases} (\mathbf{B}_2 - \mathbf{B}_1) \cdot \mathbf{n} = 0 \\ \mathbf{n} \times (\mathbf{H}_2 - \mathbf{H}_1) = \mathbf{K}_f \end{cases}$	Interface BC (5.86)
$\mathbf{E} = -\nabla\Phi$	Electric field in terms of scalar potential (1.16)	$\mathbf{H} = -\nabla\Phi_M$	Magnetic scalar potential (5.93)
$\Phi(\mathbf{x}) = \frac{1}{4\pi\epsilon_0} \int \frac{\rho(\mathbf{x}')}{ \mathbf{x} - \mathbf{x}' } d^3x'$	Scalar potential in terms of charge density (1.17)	$\mathbf{J}_M = \nabla \times \mathbf{M}, \quad \mathbf{K}_b = \mathbf{M} \times \mathbf{n}$	Bound current density (G. 6.13,14)
$\nabla^2\Phi = -\rho/\epsilon_0$	Poisson Equation (1.28)	$\rho_M = -\nabla \cdot \mathbf{M}, \quad \sigma_M = \mathbf{n} \cdot \mathbf{M}$	Effective magnetic charge density (5.96,99)
$\Phi(\mathbf{x}) = \langle \Phi \rangle_S + \frac{1}{4\pi\epsilon_0} \int_V \rho(\mathbf{x}') G_N(\mathbf{x}, \mathbf{x}') d^3x + \frac{1}{4\pi} \oint_S \frac{\partial \Phi}{\partial n'} G_N da'$	NBCs (1.46)	$\Phi_M(\mathbf{x}) = \frac{\mathbf{m} \cdot \mathbf{x}}{4\pi r^3}$	Magnetic scalar potential of dipole (J. pg. 196)
$\frac{1}{ \mathbf{x} - \mathbf{x}' } = 4\pi \sum_{\ell=0}^{\infty} \sum_{m=-\ell}^{\ell} \frac{1}{2\ell+1} \frac{r_{<}^{\ell}}{r_{>}^{\ell+1}} Y_{\ell m}^*(\theta', \phi') Y_{\ell m}(\theta, \phi)$	GFE: r, θ, ϕ (3.70)	$\mathbf{m} = \int \mathbf{M} d^3x$	Total magnetic moment (J. pg. 197)
$\frac{1}{ \mathbf{x} - \mathbf{x}' } = \frac{2}{\pi} \sum_{m=-\infty}^{\infty} \int_0^{\infty} dk e^{im(\phi - \phi')} \cos[k(z - z')] I_m(k\rho_{<}) K_m(k\rho_{>})$	GFE (3.148)	$\nabla^2 \mathbf{A} = -\mu_0 \mathbf{J}_M$	Poisson equation in terms of magnetic vector potential (5.101)
Where $r_{<} (r_{>})$ [$\rho_{<} (\rho_{>})$] is the smaller (larger) of $ \mathbf{x} $ and $ \mathbf{x}' $		$\mathbf{A}(\mathbf{x}) = \frac{\mu_0}{4\pi} \int_V \frac{\nabla' \times \mathbf{M}(\mathbf{x}')}{ \mathbf{x} - \mathbf{x}' } d^3x + \frac{\mu_0}{4\pi} \oint_S \frac{\mathbf{M}(\mathbf{x}') \times \mathbf{n}'}{ \mathbf{x} - \mathbf{x}' } da'$	Discontinuous \mathbf{M} (5.103)
$\Phi(\mathbf{x}) = \frac{1}{4\pi\epsilon_0} \sum_{l=0}^{\infty} \sum_{m=-l}^l \frac{4\pi}{2l+1} q_{lm} \frac{Y_{lm}}{r^{l+1}}$	Potential outside spher of charge (4.1)	$\Phi_M(r, \theta) = \frac{1}{3} M_0 a^2 \frac{r_{<}}{r_{>}^2} \cos \theta$	Sphere with $\mathbf{M} = M_0 \hat{\mathbf{z}}$ [$(r_{<}, r_{>})$, (r, a)] (5.104)
$q_{lm} = \int Y_{lm}^*(\theta', \phi') r'^l \rho(\mathbf{x}') d^3x'$	Multipole moments (4.3)	$\mathbf{M} = \frac{3}{\mu_0} \left(\frac{\mu - \mu_0}{\mu + 2\mu_0} \right) \mathbf{B}_0$	Permeable sphere in uniform magnetic field \mathbf{B}_0 (5.115)
$q = \int \rho(\mathbf{x}') d^3x'$	Monopole (4.4)	$F = \int_S \mathbf{B} \cdot \mathbf{n} \, da$	Magnetic flux (5.133)
$\mathbf{p} = \int \mathbf{x}' \rho(\mathbf{x}') d^3x'$	Dipole (4.8)	$\mathcal{E} = \oint_C \mathbf{E}' \cdot d\mathbf{l}$	Electromotive force (5.134)
$Q_{ij} = \int (3x_i' x_j' - r' \delta_{ij}) \rho(\mathbf{x}') d^3x' = 3M_{ij} - \text{Tr}(\mathbf{M} \delta_{ij})$	Quadrupole (4.9)	$\mathcal{E} = -k \frac{dF}{dt}$	Faraday's Law (5.135)
$M_{ij} = \int x_i' x_j' \rho(\mathbf{x}') d^3x$	Dana definition	$W = \frac{1}{2} \int \mathbf{J} \cdot \mathbf{A} d^3x$	Energy to ramp current from zero (4.83)::(5.149)
$\Phi(\mathbf{x}) = \frac{1}{4\pi\epsilon_0} \left[\frac{q}{r} + \frac{\mathbf{p} \cdot \mathbf{x}}{r^3} + \frac{1}{2} \sum_{i,j} Q_{ij} \frac{x_i x_j}{r^5} + \dots \right]$	Multipole Expansion (4.10)	$W = \frac{1}{2} \int \mathbf{H} \cdot \mathbf{B} d^3x$	Magnetic energy in fields (4.89)::(5.148)
$\mathbf{D} = \epsilon_0 \mathbf{E} + \mathbf{P}$	Electric displacement(4.34)	$\frac{dW}{dt} = \int \mathbf{H} \cdot \frac{d\mathbf{B}}{dt} d^3x$	Power in magetic field (5.147)
$\mathbf{P} = \epsilon_0 \chi_e \mathbf{E}$	Induced polarization (4.36)	$\Delta W = \frac{1}{2} \int_{V_1} \mathbf{M} \cdot \mathbf{B}_0 d^3x$	Energy to place permeable object in \mathbf{B}_0 (4.93)::(5.150)
$\mathbf{P} = (\epsilon - \epsilon_0) \mathbf{E}$	Better expression for polarization	$\frac{dW}{dt} = - \int \mathbf{J} \cdot \mathbf{E} d^3x$	Change in energy due to EMF
$\mathbf{D} = \epsilon \mathbf{E}$	Electric displacement (4.37)	$W = \frac{\mu_0}{2} \int \mathbf{H} ^2 d^3x = \frac{\mu_0}{2} \sum_{i=1}^N \sum_{j=1}^N \int \Phi_{M_j}(\mathbf{x}) \rho_{M_i}(\mathbf{x}) d^3x$	N ferromagnets (HW 8.2b)
$\epsilon = \epsilon_0 (1 + \chi_e)$	Electric permittivity (4.38)	$W = \frac{1}{2} \sum_{i=1}^N L_i I_i^2 + \sum_{i=1}^N \sum_{j>i}^N M_{ij} I_i I_j$	Inductive energy (5.152)
$\sigma_b = \mathbf{P} \cdot \hat{\mathbf{n}}, \quad \rho_b = -\nabla \cdot \mathbf{P}$	Electric bound charge density (G. 4.11)	$M_{ij} = \frac{1}{I_j} F_{ij}$	Mutual inductance (5.156)
$\begin{cases} (\mathbf{D}_2 - \mathbf{D}_1) \cdot \mathbf{n}_{21} = \sigma \\ (\mathbf{E}_2 - \mathbf{E}_1) \times \mathbf{n}_{21} = 0 \end{cases}$	Boundary conditions (4.40)	$B_z(\rho, z) \approx B_z(0, z) - \left(\frac{\rho^2}{4} \right) \left[\frac{\partial^2 B_z(0, z)}{\partial z^2} \right] + \dots$	
$\begin{cases} \Phi_{\text{in}} = - \left(\frac{3}{\epsilon/\epsilon_0 + 2} \right) E_0 r \cos \theta \\ \Phi_{\text{out}} = -E_0 r \cos \theta + \left(\frac{\epsilon/\epsilon_0 - 1}{\epsilon/\epsilon_0 + 2} \right) E_0 \frac{a^3}{r^2} \cos \theta \end{cases}$	Dielectric sphere in $\mathbf{E} = E_0 \hat{\mathbf{z}}$ (4.54)	$B_{\rho}(\rho, z) \approx - \left(\frac{\rho}{2} \right) \frac{\partial B_z(0, z)}{\partial z} + \dots$	B_z known $\mathbf{J} = 0$, ϕ -sym, near origin (J Pr. 5.4)
$W = \int \rho(\mathbf{x}) \Phi(\mathbf{x}) d^3x = \frac{1}{2} \int \mathbf{E} \cdot \mathbf{D} d^3x$	Energy to bring charges from ∞ (4.83,89)	$A_{\phi}(\rho, z) = \frac{\mu_0 I a}{\pi} \int_0^{\infty} \cos(kz) I_1(k\rho_{<}) K_1(k\rho_{>}) dk = \frac{\mu_0 I a}{2} \int_0^{\infty} J_1(ka) J_1(k\rho) dk$	\mathbf{A} of current ring (J. PR. 5.10)
$\Delta W = -\frac{1}{2} \int_{V_1} \mathbf{P} \cdot \mathbf{E}_0 d^3x$	Dielectric placed in \mathbf{E}_0 (4.93)	$\mathbf{A}_{\text{dip}} = \frac{\mu_0}{4\pi} \frac{m \sin \theta}{r^2} \Rightarrow \mathbf{B}_{\text{dip}} = \frac{\mu_0 m}{4\pi r^3} (2 \cos \theta \hat{\mathbf{r}} + \sin \theta \hat{\boldsymbol{\theta}})$	Field of dipole (G 5.87,88)
$W = q\Phi(0) - \mathbf{p} \cdot \mathbf{E}(0) - \frac{1}{6} \sum_i \sum_j Q_{ij} \frac{\partial E_j}{\partial x_i}(0) + \dots$	Work multipole expsn. (4.24)	$\tau = I \alpha = - \frac{\partial W}{\partial \theta} = \mathbf{r} \times \mathbf{F}$	Mechanical torque
$\mathbf{N} = \mathbf{p} \times \mathbf{E}$	Torque on electric dipole (G. 4.4)	$I = \int r^2 \rho(x, y, z) d^3x$	Moment of inertia
$\mathbf{F} = (\mathbf{P} \cdot \nabla) \mathbf{E}$	Force on electric dipole (G. 4.5)	$\frac{\partial^2 W}{\partial q^2} > 0 \Rightarrow \text{Stable}, \quad \frac{\partial^2 W}{\partial q^2} = 0 \Rightarrow \text{Saddle}, \quad \frac{\partial^2 W}{\partial q^2} < 0 \Rightarrow \text{Unstable}$	
$\Phi = -E_0 \left(r - \frac{a^3}{r^2} \right)$	Electric potential of conducting sphere in $\mathbf{E} = E_0 \hat{\mathbf{z}}$ (2.14)	$(a+x)^n = a^n + na^{n-1}x + \frac{n(n-1)}{2!} a^{n-2}x^2 + \dots =$	Binomial Expansion
$E_r = \frac{2p \cos \theta}{4\pi\epsilon_0}, \quad E_{\theta} = \frac{2p \sin \theta}{4\pi\epsilon_0}$	Electric dipole at origin in $\hat{\mathbf{z}}$ (4.12)	$f(x) \approx f(a) + \frac{f'(a)}{1!} (x-a) + \frac{f''(a)}{2!} (x-a)^2 + \dots$	Taylor Series
$\mathbf{E}(\mathbf{x}) = \frac{3\mathbf{n}(\mathbf{p} \cdot \mathbf{n}) - \mathbf{p}}{4\pi\epsilon_0 \mathbf{x} - \mathbf{x}_0 ^3}$	\mathbf{E} -field due to dipole \mathbf{p} (4.13)	$\begin{pmatrix} \hat{\rho} \\ \hat{\phi} \\ \hat{\mathbf{z}} \end{pmatrix} = \begin{pmatrix} \cos \phi & \sin \phi & 0 \\ -\sin \phi & \cos \phi & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} \hat{\mathbf{x}} \\ \hat{\mathbf{y}} \\ \hat{\mathbf{z}} \end{pmatrix}, \quad \begin{pmatrix} \hat{\mathbf{r}} \\ \hat{\boldsymbol{\theta}} \\ \hat{\boldsymbol{\phi}} \end{pmatrix} = \begin{pmatrix} \sin \theta \cos \phi & \sin \theta \sin \phi & \cos \theta \\ \cos \theta \cos \phi & \cos \theta \sin \phi & -\sin \theta \\ -\sin \phi & \cos \phi & 0 \end{pmatrix} \begin{pmatrix} \hat{\mathbf{x}} \\ \hat{\mathbf{y}} \\ \hat{\mathbf{z}} \end{pmatrix}$	
$\mathbf{N} = \mathbf{m} \times \mathbf{B}$	Torque on magnetic dipole moment (5.1)	$\begin{pmatrix} \hat{\mathbf{r}} \\ \hat{\boldsymbol{\theta}} \\ \hat{\boldsymbol{\phi}} \end{pmatrix} = \begin{pmatrix} \sin \theta & 0 & \cos \theta \\ \cos \theta & 0 & -\sin \theta \\ 0 & 1 & 0 \end{pmatrix} \begin{pmatrix} \hat{\rho} \\ \hat{\phi} \\ \hat{\mathbf{z}} \end{pmatrix}, \quad \begin{pmatrix} \hat{\rho} \\ \hat{\phi} \\ \hat{\mathbf{z}} \end{pmatrix} = \begin{pmatrix} \rho/\sqrt{\rho^2 + z^2} & z/\sqrt{\rho^2 + z^2} & 0 \\ 0 & 0 & 1 \\ z/\sqrt{\rho^2 + z^2} & -\rho/\sqrt{\rho^2 + z^2} & 0 \end{pmatrix} \begin{pmatrix} \hat{\mathbf{r}} \\ \hat{\boldsymbol{\theta}} \\ \hat{\boldsymbol{\phi}} \end{pmatrix}$	
$\nabla \cdot \mathbf{J} = 0$	Condition of magnetostatics (5.3)		
$d\mathbf{B} = kI \frac{d\mathbf{l} \times \mathbf{x}}{ \mathbf{x} ^3}$	Biot-Savart Law (5.4)		
$\oint_C \mathbf{B} \cdot d\mathbf{l} = \mu_0 I$	Ampère's law (5.25)		
$\mathbf{B}(\mathbf{x}) = \nabla \times \mathbf{A}(\mathbf{x})$	Magnetic vector potential (5.27)		
$\mathbf{A}(\mathbf{x}) = \frac{\mu_0}{4\pi} \int \frac{\mathbf{J}(\mathbf{x}')}{ \mathbf{x} - \mathbf{x}' } d^3x'$	Magnetic vector potential of current distribution (5.32)		
$\mathbf{m} = \frac{1}{2} \int \mathbf{x}' \times \mathbf{J}(\mathbf{x}') d^3x$	Magnetic moment definition (5.54)		
$\mathbf{m} = \frac{I}{2} \oint \mathbf{x} \times d\mathbf{l}$	Magnetic moment of closed circuit (J. pg. 186)		
$ \mathbf{m} = I \times (\text{Area})$	Magnetic moment of plane loop (5.57)		
$\mathbf{A}(\mathbf{x}) = \frac{\mu_0}{4\pi} \frac{\mathbf{m} \times \mathbf{x}}{ \mathbf{x} ^3}$	Dipole vector potential (5.55)		
$\mathbf{B}(\mathbf{x}) = \frac{\mu_0}{4\pi} \left[\frac{3\mathbf{n}(\mathbf{n} \cdot \mathbf{m}) - \mathbf{m}}{ \mathbf{x} ^3} \right]$	Dipole induction (5.56)		
$\mathbf{F} = \nabla(\mathbf{m} \cdot \mathbf{B})$	Force on dipole (5.69)		