Exam 2 Prep.

Ch 4 Electric Fields in Matter

4.1 Polarization

4.1.1 Dielectrics

4.1.2 Induced Dipoles

4.1.3 Alignment of Polar Molecules

4.1.4 Polarization

4.2 The Field of a Polarized Object

4.2.1 Bound Charges

4.2.2 Physical Interpretation of Bound Charges

4.2.3 The Field Inside a Dielectric

4.3 The Electric Displacement

4.3.1 Gauss's Law in the Presence of Dielectrics

4.3.2 A Deceptive Parallel

4.3.3 Boundary Conditions

4.4 Linear Dielectrics

4.4.1 Susceptibility, Permittivity, Dielectric Constant

4.4.2 Boundary Value Problems with Linear Dielectrics

4.4.3 Energy in Dielectrics

4.4.4 Forces on Dielectrics

Ch 5. Magnetostatics

5.1 The Lorentz Force Law

5.1.1 the Magnetic Field

5.1.2 Magnetic Forces

$$\vec{F} = Q\left[\vec{E} + \left(\vec{v} \times \vec{B}\right)\right]$$

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- **Cyclotron motion**

  .4 $QvB = m\left(v^2/R\right)$ or $p = mv = QBR$
- **Magnetic Force does no work**

5.1.3 Currents

$$\vec{I} = \frac{d\vec{q}}{dt} = \frac{dq}{dx}\frac{d\vec{x}}{dt} = \lambda\vec{v} \qquad \vec{K} = \frac{d\vec{I}}{dl_\perp} = \sigma\vec{v} \qquad \vec{J} = \frac{d\vec{I}}{da_\perp} = \rho\vec{v}$$

$$\vec{F}_{mag} = \sum q_i\vec{v}_i \times \vec{B} = \int \rho d\tau\vec{v} \times \vec{B} = \int \rho\vec{v} \times \vec{B}d\tau = \int \vec{J} \times \vec{B}d\tau$$

$$\vec{F}_{mag} = \int \sigma\vec{v} \times \vec{B}dA = \int \vec{K} \times \vec{B}dA$$

$$\vec{F}_{mag} = \int \lambda\vec{v} \times \vec{B}dl = \int \vec{I} \times \vec{B}dl$$

Continuity Equation

$$\vec{\nabla} \cdot \vec{J} = -\frac{d\rho}{dt}$$

5.2 Biot-Savart Law

$$\vec{B}(\vec{r}) = \frac{\mu_0}{4\pi}\int \frac{(dq'\vec{v}) \times \hat{\mathscr{r}}}{\mathscr{r}^2}$$

$$\vec{B}(\vec{r}) = \frac{\mu_0}{4\pi}\int \frac{(d\ell'\vec{I}) \times \hat{\mathscr{r}}}{\mathscr{r}^2}$$

(for constant currents)

$$\vec{B}(\vec{r}) = \frac{\mu_0}{4\pi}\int \frac{(da'\vec{K}) \times \hat{\mathscr{r}}}{\mathscr{r}^2}$$

$$\vec{B}(\vec{r}) = \frac{\mu_0}{4\pi}\int \frac{(d\tau'\vec{J}) \times \hat{\mathscr{r}}}{\mathscr{r}^2}$$

Examples: straight line segment

Loops built of straight line segments (square, triangle)

Circular loop

Solenoid

Spinning disc

5.3 Divergence and Curl of B

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

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Ampere's Law

$$\vec{\nabla} \times \vec{B}_{line} = \mu_o \vec{J}\,, \qquad \oint \vec{B}_{line} \cdot d\vec{l} = \mu_o I_{encl}$$

Applications of Ampere's Law

Examples: wire, coaxial cable, sheet, solenoid, toroid

5.4 Vector Potential

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

Can choose $\vec{\nabla} \cdot \vec{A} = 0$

Then $\nabla^2 \vec{A} = -\mu_0 \vec{J}$

$$\vec{A}(\vec{r}) = \frac{\mu_0}{4\pi} \int \frac{\vec{J}(\vec{r}\,')}{\boldsymbol{\mathscr{r}}} d\tau'$$

$$\oint \vec{A} \cdot d\vec{\ell} = \int \vec{B} \cdot d\vec{a} = \Phi$$

Examples: sphere, solenoid, sheet, wire

Multipole expansion

$\vec{A}_{dip}(\vec{r}) = \dfrac{\mu_0}{4\pi} \dfrac{\vec{m} \times \hat{r}}{r^2}$ where $m \equiv I \int d\vec{a}'$

Examples: ring, and things built of rings: disc, solenoid, sphere.

$\vec{A}_{dip}(\vec{r}) = \dfrac{\mu_0}{4\pi} \dfrac{m \sin\theta}{r^2} \hat{\phi}$ (for m in z direction)

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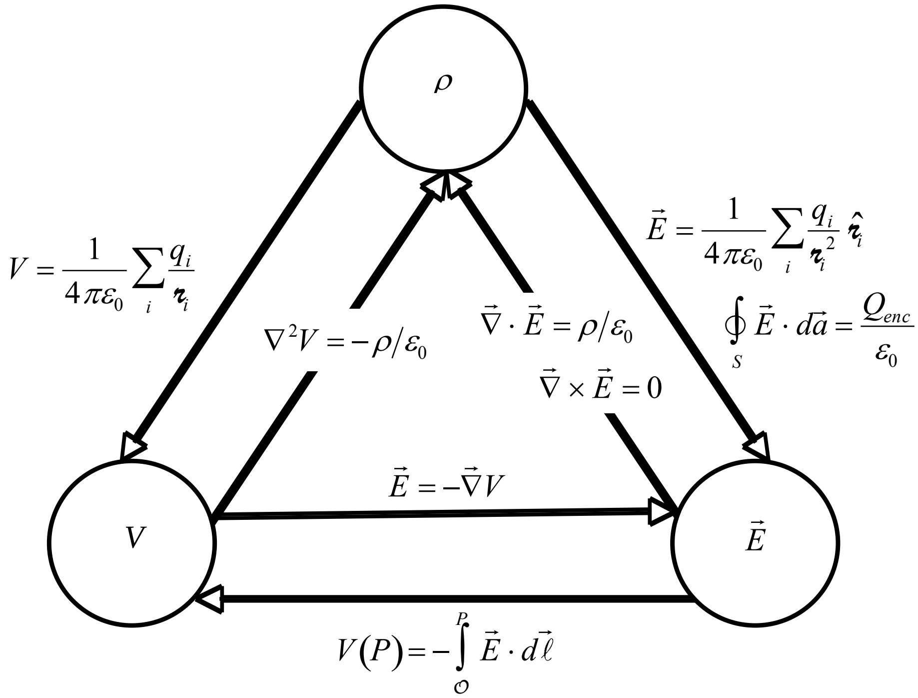
<u>Potentially Useful Information</u>

<u>Electrostatics</u>:



$\varepsilon_0 = 8.85\times10^{-12}\ \mathrm{C^2/(N\cdot m^2)}$ $\qquad$ $\vec{F}_{elec} = Q\vec{E}$

$E^{\perp}_{\text{above}} - E^{\perp}_{\text{below}} = \frac{1}{\varepsilon_0}\sigma$ $\qquad$ $\vec{E}^{\parallel}_{\text{above}} = \vec{E}^{\parallel}_{\text{below}}$ $\qquad$ $V_{\text{above}} = V_{\text{below}}$

$W_{a\to b} = Q[V(b) - V(a)]$ $\qquad$ $C = Q/V$

$V_{mon}(\vec{r}) = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r}$ $\qquad$ $V_{dip}(\vec{r}) = \frac{1}{4\pi\varepsilon_0}\frac{\vec{p}\cdot\hat{r}}{r^2}$ $\qquad$ $\vec{p} = \sum q_i\vec{r}_i'$

$\vec{N} = \vec{p}\times\vec{E}$ $\qquad$ $U = -\vec{p}\cdot\vec{E}$ $\qquad$ $\vec{F} = \vec{\nabla}(\vec{p}\cdot\vec{E})$

$$\vec{E}_{dip} = \frac{p}{4\pi\varepsilon_0 r^3}\left(2\cos\theta\ \hat{r} + \sin\theta\ \hat{\theta}\right)$$

$\sigma_b = \vec{P}_{surf}\cdot\hat{n}$ $\qquad$ $\rho_b = -\vec{\nabla}\cdot\vec{P}$

$\vec{D} = \varepsilon_0\vec{E} + \vec{P}$ $\qquad$ $\vec{\nabla}\cdot\vec{D} = \rho_f$ $\qquad$ $\int \vec{D}\cdot d\vec{a} = Q_{f,enc}$

$\vec{P} = \varepsilon_0\chi_e\vec{E}$ $\qquad$ $\vec{D} = \varepsilon\vec{E}$

$\varepsilon = \varepsilon_0(1+\chi_e)$ $\qquad$ $\varepsilon_r = \varepsilon/\varepsilon_0 = 1 + \chi_e$

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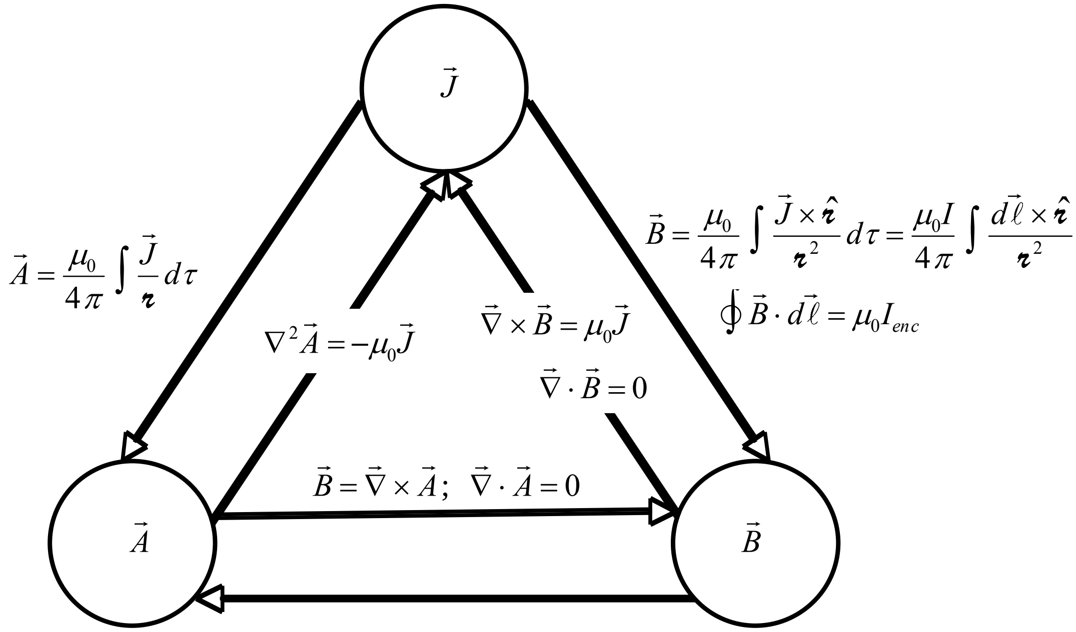
Magnetostatics: $\vec{\nabla}\cdot\vec{J} = -\partial\rho/\partial t \xrightarrow{\text{magnetostatics}} 0$



$\mu_0 = 4\pi\times 10^{-7}\,\text{N/A}^2$ $\qquad$ $1\,\text{T} = 1\,\text{N/(A}\cdot\text{m)}$ $\qquad$ $\vec{F}_{mag} = Q\vec{v}\times\vec{B} \xrightarrow{wire} I\int d\vec{\ell}\times\vec{B}$

$B^{\perp}_{\text{above}} = B^{\perp}_{\text{below}}$ $\qquad$ $B^{\parallel}_{\text{above}} - B^{\parallel}_{\text{below}} = \mu_0 K$ $\qquad$ $\vec{A}_{\text{above}} = \vec{A}_{\text{below}}$

$\vec{A}_{dip}(\vec{r}) = \frac{\mu_0}{4\pi}\frac{\vec{m}\times\hat{r}}{r^2}$ $\qquad$ $\vec{m} = I\vec{a}$

Specific Results:

$$\vec{B}_{wire} = \frac{\mu_0 I}{2\pi s}\hat{\phi} \qquad \vec{B}_{loop} = \frac{\mu_0 I}{2}\frac{R^2}{\left(R^2+z^2\right)^{3/2}}\,\hat{z}$$