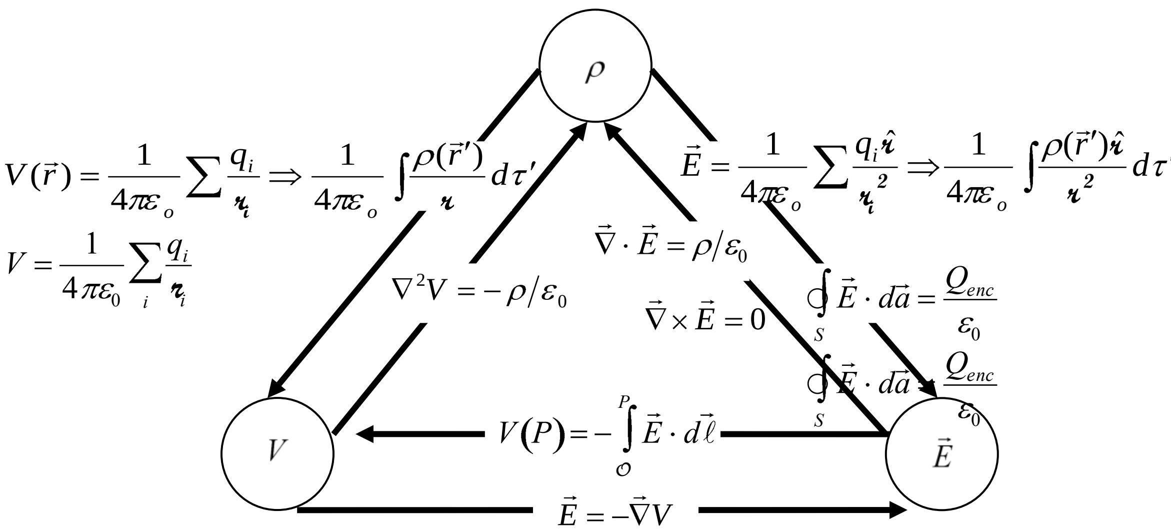
Instructions

- Write your name on the front of your blue book before you start working.
- Start the solution to each problem on a new page. They don't need to be in order, but clearly label them. Cross out any work that you don't want graded.
- Just getting the right answer will only earn you a small fraction of the possible credit on a problem. In order to receive full credit, provide a complete solution.
- Show all of your work.
- Be sure to include correct units with all numerical quantities, not just with your final answers. You must also use proper notation.

Potentially Useful Information

Electrostatics:



$\varepsilon_0 = 8.85\times10^{-12}\ \mathrm{C^2/(N\cdot m^2)}$ $\quad \vec{F}_{elec} = Q\vec{E}$ $\quad W_{a\to b} = Q[V(b) - V(a)]$ $\quad C = Q/V$

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

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

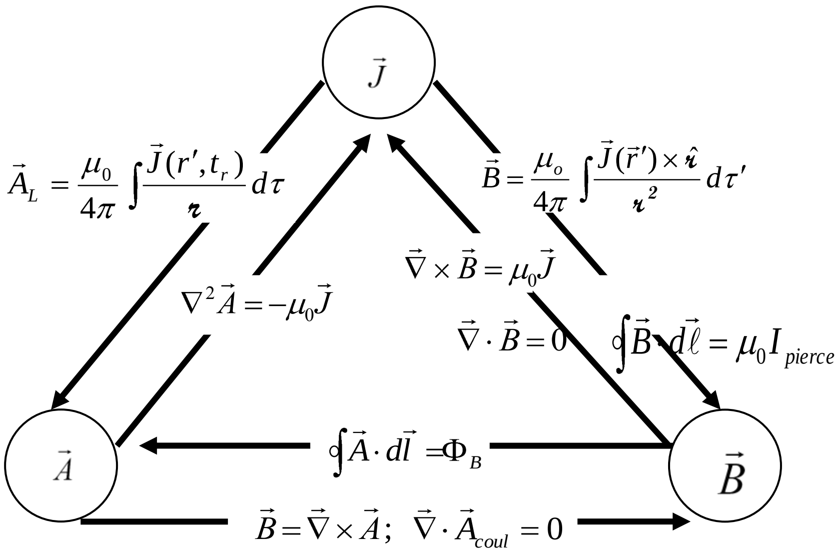
$\vec{E}_{dip} = \frac{p}{4\pi\varepsilon_0 r^3}\left(2\cos\theta\,\hat{r} + \sin\theta\,\hat{\theta}\right)$ $\quad \vec{N} = \vec{p}\times\vec{E}$ $\quad U = -\vec{p}\cdot\vec{E}$ $\quad \vec{F} = (\vec{p}\cdot\vec{\nabla})\vec{E}$

$\vec{P} \equiv \frac{d\vec{p}}{d\tau}$ $\quad \sigma_b = \vec{P}_{surf}\cdot\hat{n}$ $\quad \rho_b = -\vec{\nabla}\cdot\vec{P}$

$\vec{D} \equiv \varepsilon_o\vec{E} + \vec{P}$ $\quad \vec{\nabla}\cdot\vec{D} = \rho_f$ $\quad \int \vec{D}\cdot d\vec{a} = Q_{f,encl}$

$\vec{P} = \varepsilon_o\chi_e\vec{E}$ $\quad \vec{D} = \varepsilon\vec{E}$ $\quad \varepsilon = \varepsilon_0(1+\chi_e)$ $\quad \varepsilon_r = \varepsilon/\varepsilon_0 = 1 + \chi_e$

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



$\Phi_B \equiv \int \vec{B}\cdot d\vec{a}$

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

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

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

$\vec{A}_{dip}(\vec{r}) = \frac{\mu_0}{4\pi}\frac{\vec{m}\times\hat{r}}{r^2}$ $\quad \vec{m} \equiv I\vec{a}$ $\quad \vec{B}_{dip} = \frac{\mu_0 m}{4\pi r^3}\left(2\cos\theta\,\hat{r} + \sin\theta\,\hat{\theta}\right)$

$\vec{N} = \vec{m}\times\vec{B}$ $\quad U = -\vec{m}\cdot\vec{B}$ $\quad \vec{F} = \vec{\nabla}\left(\vec{m}\cdot\vec{B}\right)\Big|_{m=const}$

$\vec{M} \equiv \frac{d\vec{m}}{d\tau}$ $\quad \vec{K}_b = \vec{M}_{surf}\times\hat{n}$ $\quad \vec{J}_b = \vec{\nabla}\times\vec{M}$

$\vec{H} \equiv \frac{1}{\mu_o}\vec{B} - \vec{M}$ $\quad \vec{\nabla}\times\vec{H} = \vec{J}_f$ $\quad \oint \vec{H}\cdot d\vec{l} = I_{f,pierce}$

$\vec{M} = \chi_m\vec{H}$ $\quad \vec{B} = \mu\vec{H}$ $\quad \mu = \mu_0\left(1+\chi_m\right)$

Dynamics:

$\vec{J} = \sigma\vec{E}$ $\qquad V = IR$ $\qquad P = IV$

$$emf_2 = -\frac{d\Phi_2}{dt} = -M_{1,2}\frac{dI_1}{dt} \qquad \varepsilon = -L\frac{dI}{dt}$$

$$\vec{\nabla}\times\vec{B} - \mu_o\varepsilon_o\frac{\partial}{\partial t}\vec{E} = \mu_o\vec{J} \qquad \oint\vec{B}\cdot d\vec{\ell} - \mu_0\varepsilon_0\left.\frac{\partial\Phi_E}{\partial t}\right|_{A=const} = \mu_0 I_{enc}$$

$$\vec{\nabla}\times\vec{E} = -\frac{\partial}{\partial t}\vec{B} \qquad emf = -\frac{\partial\Phi_B}{\partial t} \qquad emf = \oint\vec{E}\cdot d\vec{\ell}$$

$$\vec{E} = -\vec{\nabla}V - \frac{\partial\vec{A}}{\partial t} \qquad \nabla^2 V + \frac{\partial}{\partial t}\vec{\nabla}\cdot\vec{A} = -\rho/\varepsilon_0$$

$$\vec{A}' = \vec{A} + \vec{\nabla}\lambda \qquad V' = V - \frac{\partial\lambda}{\partial t}$$

$$V_L(\vec{r},t) = \frac{1}{4\pi\varepsilon_o}\int\frac{\rho(\vec{r}\,',t_r)}{\mathscr{r}}d\tau' \qquad \vec{A}_L(\vec{r},t) = \frac{\mu_o}{4\pi}\int\frac{\vec{J}(\vec{r}\,',t_r)}{\mathscr{r}}d\tau' \qquad \text{Where } t_r \equiv t - \frac{\mathscr{r}}{c}$$

$$V_L(\vec{r},t) = \frac{1}{4\pi\varepsilon_o}\frac{qc}{\mathscr{r}c - \vec{v}\cdot\vec{\mathscr{r}}} \qquad \vec{A}_L(\vec{r},t) = \frac{\vec{v}}{c^2}V_L(\vec{r},t)$$

$$\vec{E} = \frac{1}{4\pi\varepsilon_o}\int\left(\frac{\dot{\rho}(\vec{r}\,',t_r)\hat{\mathscr{r}}}{c\mathscr{r}} + \frac{\rho(\vec{r}\,',t_r)\hat{\mathscr{r}}}{\mathscr{r}^2} - \frac{\dot{\vec{J}}(\vec{r}\,',t_r)}{c^2\mathscr{r}}\right)d\tau' \qquad \vec{B}(\vec{r},t) = \frac{\mu_o}{4\pi}\int\left(\frac{\dot{\vec{J}}(\vec{r}\,',t_r)}{c\mathscr{r}} + \frac{\vec{J}(\vec{r}\,',t_r)}{\mathscr{r}^2}\right)\times\hat{\mathscr{r}}\,d\tau'$$

$$\vec{E}(r,t) = \frac{q}{4\pi\varepsilon_o}\frac{\mathscr{r}}{(\vec{\mathscr{r}}\cdot\vec{u})^3}\left[(c^2 - v^2)\vec{u} + \vec{\mathscr{r}}\times(\vec{u}\times\vec{a})\right] \qquad \vec{B} = \frac{1}{c}\hat{\mathscr{r}}\times\vec{E} \qquad \text{Where } \vec{u} \equiv c\hat{\mathscr{r}} - \vec{v}$$

Ch7 Electrdynamics

7.1 Electromotive Force
- 7.1.1 Ohm’s Law
- 7.1.2 Electromotive Force
- 7.1.3 Motional emf

7.2 Electrmagnetic Induction
- 7.2.1 Faraday’s Law
- 7.2.2 The Induced Electric Field
- 7.2.3 Inductance
- 7.2.4 Energy inMagnetic Fields

7.3 Maxwell’s Equations
- 7.3.1 Electrodynamics Before Maxwell
- 7.3.2 How Maxwell fixed Ampere’s Law
- 7.3.3 Maxwell’s Equations

Ch 10 Potential sand Fields

10.1 The Potential Formulation
- 10.1.1 Scalar and Vector Potentials
- 10.1.2 Gauge Transformations
- 10.1.3 Coulomb Gauge and Lorentz Gauge

10.2 Continuous Distributions
- 10.2.1 Retarded Potentials
- 10.2.2 Jefimenko’s Equations

10.3 Point Charges
- 10.3.1 Lienard-Wiechart Potentials
- 10.3.2 The Fields of a Moving Point Charge

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. 6 Magnetic Fields in Matter

6.1 Magnetization