Constants: $k_e = 8.99\times10^{9} Nm^2/C^2$; $\varepsilon_o = \frac{1}{4\pi k_e} = 8.85\times10^{-12} F/m$; $\mu_o = 4\pi\times10^{-7} N/A^2$; $e = 1.602\times10^{-19} C$

$m_e = 9.11\times10^{-31} kg$; $m_p = 1.67\times10^{-27} kg$; $N_A = 6.02\times10^{23}\ items/mole$; $G = 6.67\times10^{-11} Nm^2/kg^2$

Dielectric strength of air = 30,000 V/cm = 3 MV/m

Units: $V = \frac{kg*m^2}{A*s^3} = \frac{J}{C} = \frac{N*m}{C} = \frac{W}{A} = \frac{W*s}{C} = \frac{Wb}{s} = \frac{T*m^2}{s} = \frac{C}{F} = A*\Omega = \frac{H*A}{s}$

Electric Field:

$\vec{\mathbf{F}}_{q_o} = q_o\vec{\mathbf{E}}\left(\vec{\mathbf{r}}_{q_o}\right)$ $\vec{\mathbf{E}}(\vec{\mathbf{r}}_o) = k_e\sum_i \frac{Q_i}{r_{io}^2}\hat{\mathbf{r}}_{io}$ $\vec{\mathbf{E}}(\vec{\mathbf{r}}_o) = k_e\int_{\substack{charge\\distribution}} \frac{dq}{r_{qo}^2}\hat{\mathbf{r}}_{qo}$ $\vec{\mathbf{E}}_{point}(\vec{\mathbf{r}}) = \frac{k_e q}{r^2}\hat{\mathbf{r}}$ $E_{line} = \frac{2k_e\lambda}{r}\hat{\mathbf{r}}$ $\vec{\mathbf{E}}_{plane}(\vec{\mathbf{r}}) = \frac{\sigma}{2\varepsilon_o}(out)$

Electric Potential & Potential Energy

$\Delta U = q\Delta V = -W_{by\ field}$ $\Delta U = U_b - U_a = -\int_a^b \vec{\mathbf{F}}\bullet d\vec{\ell}$ $U_{\substack{2\ point\\charges}} = k_e\frac{q_1q_2}{r_{12}}$

$\Delta V = V_b - V_a = -\int_a^b \vec{\mathbf{E}}\bullet d\vec{\ell}$ $E_x = -\frac{\partial V}{\partial x}$ $V_{point}(r) = \frac{k_e q}{r} - \frac{k_e q}{R_{ref}}$ $V_{line}(R) = 2k_e\lambda\ln\frac{R}{R_{ref}}$ $V(r) = k_e\int_{\substack{charge\\distribution}} \frac{dq}{r}$

Conductor at Equilibrium

E = 0 *inside*; $E = \frac{\sigma_{surface}}{\varepsilon_o}$ *just outside; V = constant.*

Gauss' Law and Coulomb's Law

$\vec{\mathbf{F}}_{12} = k_e\frac{q_1q_2}{r_{12}^2}\hat{\mathbf{r}}_{12}$; $\vec{\mathbf{r}}_{12} = \vec{\mathbf{r}}_1 - \vec{\mathbf{r}}_2$ $\Phi_e = \iint \vec{\mathbf{E}}\bullet d\vec{\mathbf{A}} = \iint\left(\vec{\mathbf{E}}\bullet\hat{\mathbf{n}}\right)dA$ $\Phi_E^{net} = \oiint_{\substack{closed\\surface}} \vec{\mathbf{E}}\bullet d\vec{\mathbf{A}} = \frac{q_{encl}}{\varepsilon_o} = \frac{1}{\varepsilon_o}\iiint_{\substack{enclosed\\surface}} \rho d^3x$

Capacitance

$Q = CV;\ V = \frac{Q}{C}$; $U = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}\frac{1}{C}Q^2 = \frac{1}{2}\kappa\varepsilon_o E^2 * volume$

$C_{parallel} = C_1 + C_2$; $C_{series} = \left(\frac{1}{C_1} + \frac{1}{C_2}\right)^{-1} = \frac{C_1C_2}{C_1 + C_2}$

parallel plate: $C_{pp} = \frac{\kappa\varepsilon_o A}{d}$; *coaxial cable*: $C_{coax} = \frac{2\pi\kappa\varepsilon_o L}{\ln\left(R_2/R_1\right)}$; *isolated sphere*: $C_{sphere} = 4\pi\kappa\varepsilon_o R$

Current and Resistance

$I = GV = \frac{V}{R}$ $I = GV = \frac{V}{R};\ V = IR = \frac{I}{G}$; $Power = I^2R = IV = \frac{V^2}{R} = J^2\rho * volume$; $\vec{\mathbf{J}} = nq\vec{\mathbf{v}}_{drift}$ $I = \iint \vec{\mathbf{J}}\bullet d\vec{\mathbf{A}}$

wire: $G = \frac{\sigma A}{L}$; $R = \frac{1}{G} = \rho\frac{L}{A}$; $R_{parallel} = \left(\frac{1}{R_1} + \frac{1}{R_2}\right)^{-1} = \frac{R_1R_2}{R_1 + R_2}$ $R_{series} = R_1 + R_2$

Inductance

$V = L\frac{dI}{dt};\ \Phi_B = LI$; $U = \frac{1}{2}LI^2 = \frac{1}{2}\frac{\Phi_B^2}{L} = \frac{1}{2}\kappa_m\mu_o B^2 * volume$; $L_{parallel} = \left(\frac{1}{L_1} + \frac{1}{L_2}\right)^{-1} = \frac{L_1L_2}{L_1 + L_2}$; $L_{series} = L_1 + L_2$

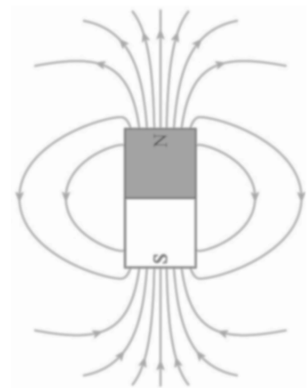
solenoid: $L = \kappa_m\mu_o n^2 A\ell$

Circuits

$\sum_{\substack{closed\\loop}} \Delta V = 0 \quad \sum_{point} I = 0 \quad Q, I, \frac{dI}{dt}$ *same in series;* ΔV *same in parallel*

capacitor charging: $Q = Q_o\left(1 - e^{-t/RC}\right); I = I_o e^{-t/RC}$; *discharging:* $Q = Q_o e^{-t/RC}; I = -I_o e^{-t/RC}$; $\tau = RC$

current building in inductor: $I = I_o\left(1 - e^{-Rt/L}\right)$; *current decreasing:* $I = I_o e^{-Rt/L}$; $\tau = \frac{L}{R}$



Magnetic Force: $\vec{\mathbf{F}}_{\substack{moving\\charge}} = q\vec{\mathbf{v}} \times \vec{\mathbf{B}}$; $d\vec{\mathbf{F}}_{\substack{current\\element}} = Id\vec{\ell} \times \vec{\mathbf{B}}$; $\vec{\mathbf{F}}_{\substack{straight\\wire}} = I\vec{\mathbf{L}} \times \vec{\mathbf{B}}$

Lorentz Force: $\vec{\mathbf{F}} = q\vec{\mathbf{E}} + q\vec{\mathbf{v}} \times \vec{\mathbf{B}}$

Magnetic Dipoles: $\vec{\mu}_{\substack{current\\loop}} = NIA\hat{\mathbf{n}}$; $U = -\vec{\mu} \bullet \vec{\mathbf{B}}$; *torque* $\vec{\tau} = \vec{\mu} \times \vec{\mathbf{B}}$

Biot-Savart Law, Ampere's Law, Gauss' Law for Magnetism:

$\vec{\mathbf{B}} = \frac{\kappa_m \mu_o}{4\pi} \frac{q\vec{\mathbf{v}} \times \hat{\mathbf{r}}}{r^2}$; $\quad d\vec{\mathbf{B}} = \frac{\kappa_m \mu_o}{4\pi} \frac{i\, d\vec{\ell} \times \hat{\mathbf{r}}}{r^2}$; $\quad \oint_{loop} \vec{\mathbf{B}} \bullet d\vec{\ell} = \mu_o I_{\substack{through\\loop}}$; $\quad \oiint_{\substack{closed\\surface}} \vec{\mathbf{B}} \bullet d\vec{\mathbf{A}} = 0$

$B_{\substack{inf\\wire}} = \frac{k_m \mu_o}{2\pi r} I$, *right thumb along I, fingers along B*; $B_{\substack{wire\\segment}} = \frac{\kappa_m \mu_o I}{4\pi R_\perp}\left(\sin\theta_2 - \sin\theta_1\right)$

$B_{\substack{long\\coil}} = n\kappa_m \mu_o I$, *right fingers along I, thumb along B*; $B_{\substack{arc\\center}} = \frac{\kappa_m \mu_o I}{4\pi R}\Delta\theta$; $B_{\substack{axis\\circular\\loop}} = \frac{\mu_o}{4\pi} \frac{2\pi R^2 I}{\left(z^2 + R^2\right)^{3/2}}$

$\vec{\mathbf{B}}_{total} = \kappa_m \vec{\mathbf{B}}_{applied} = \vec{\mathbf{B}}_{applied} + \mu_o \vec{\mathbf{M}}$

Faraday's Law, Lenz' Law and Motional *emf*:

$emf = -\frac{d\Phi_B}{dt} = -\frac{d}{dt} \iint_{\substack{loop\\interior}} \vec{\mathbf{B}} \bullet d\vec{\mathbf{A}}$; $emf_{\substack{moving\\rod}} = LvB$;

induced emf acts to counteract the change in flux

Geometry and Definitions: Surface Area: $A_{sphere} = 4\pi R^2 \quad A_{cyl} = 2\pi RH + 2\pi R^2 \quad A_{cube} = 6a^2$

Volume: $V_{sphere} = \frac{4}{3}\pi R^3 \quad V_{cyl} = \pi R^2 H \quad V_{cube} = a^3$

Linear Charge Density: $\lambda = \frac{Q}{length}$; Areal Charge Density: $\sigma = \frac{Q}{Area}$;

Volume Charge Density $\rho = \frac{Q}{volume}$ $\quad \cos 30° = \frac{\sqrt{3}}{2}; \sin 30° = \frac{1}{2}; \cos 45° = \sin 45° = \frac{\sqrt{2}}{2}$

Cross Products: $\vec{\mathbf{A}}_1 \times \vec{\mathbf{A}}_2 = \vec{\mathbf{A}}_3$: *align right hand with* $\vec{\mathbf{A}}_1$, *curl fingers toward* $\vec{\mathbf{A}}_2$ *right thumb points toward* $\vec{\mathbf{A}}_3$, *which is perpendicular to both* $\vec{\mathbf{A}}_1$ *and* $\vec{\mathbf{A}}_2$.

Kinematics:

$\vec{\mathbf{a}} = \frac{\vec{\mathbf{F}}}{m} = \frac{q}{m}\left(\vec{\mathbf{E}} + \vec{\mathbf{v}} \times \vec{\mathbf{B}}\right) \quad x = x_o + v_o t + \frac{1}{2}at^2 \quad v = v_o + at$ *Circular motion:* $a = \frac{v^2}{r}; F = ma = \frac{mv^2}{r}$