# Equation Sheet: 8.02 - F2026

**Gauss's Law:**

$$\underset{\substack{\text{closed}\\ \text{surface S}}}{\oiint} \vec{\mathbf{E}} \cdot \hat{\mathbf{n}}\, da = \frac{1}{\varepsilon_0} \underset{\substack{\text{volume}\\ \text{enclosed by S}}}{\iiint} \rho dV_{vol}$$

**Gauss's Law for Magnetism:**

$$\underset{\substack{\text{closed}\\ \text{surface S}}}{\oiint} \vec{\mathbf{B}} \cdot \hat{\mathbf{n}}\, da = 0$$

**Maxwell-Ampere's Law:**

$$\underset{\substack{\text{closed}\\ \text{path C}}}{\oint} \vec{\mathbf{B}} \cdot d\vec{\mathbf{s}} =$$
$$\underset{\substack{\text{any surface S}\\ \text{with boundary C}}}{\iint} \left( \mu_0 (\vec{\mathbf{J}} \cdot \hat{\mathbf{n}})\, da + \mu_0 \epsilon_0 \frac{d}{dt} (\vec{\mathbf{E}} \cdot \hat{\mathbf{n}}\, da) \right)$$

**Faraday's Law:**

$$\varepsilon = \underset{\substack{\text{closed}\\ \text{path C}}}{\oint} \vec{\mathbf{E}} \cdot d\vec{\mathbf{s}}$$
$$\varepsilon = - \underset{\substack{\text{any surface S}\\ \text{with boundary C}}}{\iint} \frac{d}{dt} (\vec{\mathbf{B}} \cdot \hat{\mathbf{n}}\, da)$$

**Lorentz Force Law:**

$$\vec{\mathbf{F}}_q = q(\vec{\mathbf{E}}_{ext} + \vec{\mathbf{v}}_q \times \vec{\mathbf{B}}_{ext})$$

**Current Density and Current:**

$$I = \underset{\substack{\text{open}\\ \text{surface S}}}{\iint} \vec{\mathbf{J}} \cdot \hat{\mathbf{n}}\, da$$

**Force on Current Carrying Wire:**

$$\vec{\mathbf{F}} = \int_{\text{wire}} I d\vec{\mathbf{s}} \times \vec{\mathbf{B}}_{ext}$$

**Coulomb Force Law**

$$\vec{\mathbf{F}}_{12} = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{r_{12}^2} \hat{\mathbf{r}}_{12}.$$

Force on 2 due to interaction between 1 and 2, where $\hat{\mathbf{r}}_{\mathbf{1,2}}$ points from 1 to 2.

**Source Equations**

$$\vec{\mathbf{E}}(P) = \frac{1}{4\pi\varepsilon_0} \int_{source} \frac{dq}{r_{S,P}^2} \hat{\mathbf{r}}_{S,P}$$
$$\vec{\mathbf{B}}(P) = \frac{\mu_0}{4\pi} \int_{source} \frac{I d\vec{\mathbf{s}} \times \hat{\mathbf{r}}_{S,P}}{r_{S,P}^2}$$

**Electrostatic Potential Difference Definition:**

$$\Delta V = V_b - V_a \equiv - \int_a^b \vec{\mathbf{E}} \cdot d\vec{\mathbf{s}}$$

**Electrostatic Potential Difference:**

point charge at origin: $V(r) - V(\infty) = \dfrac{1}{4\pi\varepsilon_0} \dfrac{q}{r}$

N point charges: $V(\vec{\mathbf{r}}) - V(\infty) = \dfrac{1}{4\pi\varepsilon_0} \displaystyle\sum_{i=1}^{N} \dfrac{q_i}{\left|\vec{\mathbf{r}} - \vec{\mathbf{r}}_i\right|}$

continuous charge distribution:

$$V(\vec{\mathbf{r}}) - V(\infty) = \frac{1}{4\pi\varepsilon_0} \int_{\text{source}} \frac{dq'}{\left|\vec{\mathbf{r}} - \vec{\mathbf{r}}'\right|}$$

**Electric Field from Potential:**

$$\vec{\mathbf{E}} = -\vec{\nabla} V$$

**Potential Energy:**

$$U_{\text{stored}} = \frac{1}{4\pi\varepsilon_0} \sum_{\text{all pairs}} \frac{q_i q_j}{r_{ij}} \;;\; U(\infty) = 0$$

**Potential Energy from Potential:**

$$\Delta U = q \Delta V$$

**Energy Law:**

$$q\Delta V + \Delta K = W_{nc}$$

**Energy Stored in Charge Configuration:**

$$U_{\text{stored}} = \frac{1}{4\pi\varepsilon_0} \sum_{\text{all pairs}} \frac{q_i q_j}{r_{ij}} \;;\; U(\infty) = 0$$

**Energy Density Stored in Fields:**

$u_E = \frac{1}{2}\varepsilon_0 E^2, \quad u_B = B^2/2\mu_0$

**Electric Dipole:**

Electric Dipole Moment: $\vec{\mathbf{p}}_A = \sum_{i=1}^{N} q_i \vec{\mathbf{r}}_{A,i}$

Torque: $\vec{\tau} = \vec{\mathbf{p}} \times \vec{\mathbf{E}}$

Force on a Dipole: $\vec{\mathbf{F}} = \vec{\nabla}(\vec{\mathbf{p}} \cdot \vec{\mathbf{E}}_{\text{ext}})$

Potential Energy of a Dipole: $U_E = -\vec{\mathbf{p}} \cdot \vec{\mathbf{E}}_{\text{ext}}$

Dipole Potential: $V(\vec{\mathbf{r}}) - V(\infty) = \dfrac{1}{4\pi\varepsilon_0}\dfrac{\vec{\mathbf{p}} \cdot \hat{\mathbf{r}}}{r^2}$

**Magnetic Dipole:**

Magnetic Dipole Moment: $\vec{\mu} = IA\hat{\mathbf{n}}_{RHR}$

Torque on a Dipole: $\vec{\tau} = \vec{\mu} \times \vec{\mathbf{B}}_{ext}$

Force on a Dipole: $\vec{\mathbf{F}} = \vec{\nabla}(\vec{\mu} \cdot \vec{\mathbf{B}}_{ext})$

(Special case) $F_z = \mu_z \dfrac{\partial B_{z,ext}}{\partial z}$

Potential Energy: $U_B = -\vec{\mu} \cdot \vec{\mathbf{B}}_{\text{ext}}$

**Capacitance:**

$Q = C\,|\Delta V|$

Energy Stored in Capacitor:

$U_E = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}C|\Delta V|^2$

**Conductivity and Resistivity:**

$\vec{\mathbf{J}} = \sigma_c \vec{\mathbf{E}}$ where $\sigma_c$ is the conductivity

$\vec{\mathbf{E}} = \rho_r \vec{\mathbf{J}}$ where $\rho_r$ is the resistivity

**Ohm's Law and Resistance:**

$\Delta V = I\ R$

**Power:**

$P = \vec{\mathbf{F}} \cdot \vec{\mathbf{v}}$

**Power from Voltage Source:**

$P_{\text{source}} = I\Delta V_{\text{source}}$

**Power Dissipated by a Resistor:**

$P_{\text{Joule}} = I^2 R = \Delta V^2/R$

**DC Circuit Laws:**

$\sum_{i=1}^{N} \Delta V_i = 0\ ,\ I_{\text{in}} = I_{\text{out}}$

**Magnitude of centripetal force for circular motion with radius R:**

$F_c = m\frac{v^2}{R}$

**Inductance:**

$L = \frac{\Phi_B}{I}, \quad U_B = \frac{1}{2}LI^2, \quad \varepsilon = -L\frac{dI}{dt}$

**Time Constants:**

$\tau = RC\,,\ \tau = L/R\,,\ \omega_0 = 1/\sqrt{LC}$

**Wave Equations:**

Plane Linearly Polarized Wave traveling in the $\pm x$-direction:

$$\frac{\partial E_y}{\partial x} = -\frac{\partial B_z}{\partial t}, -\frac{\partial B_z}{\partial x} = \mu_0\varepsilon_0\frac{\partial E_y}{\partial t}$$

$$\frac{\partial^2 E_y}{\partial x^2} = \frac{1}{c^2}\frac{\partial^2 E_y}{\partial t^2} \quad \frac{\partial^2 B_z}{\partial x^2} = \frac{1}{c^2}\frac{\partial^2 B_z}{\partial t^2}$$

$c = 1/\sqrt{\mu_0\varepsilon_0}$

**Properties of Waves:**

$f = 1/T \quad \omega = 2\pi f \quad k = 2\pi/\lambda$

$c = \lambda/T = \lambda f = \omega/k \quad E_0 = cB_0$

**Time Averaging:**

$\left\langle \sin^2(\omega t+\phi)\right\rangle = \frac{1}{T}\int_0^T \sin^2(\omega t+\phi)dt = \frac{1}{2}$

**Poynting Vector:**

$\vec{\mathbf{S}} = \dfrac{\vec{\mathbf{E}}\times\vec{\mathbf{B}}}{\mu_0}, \quad , \ I = \langle|\vec{\mathbf{S}}|\rangle$

Power $= \iint \vec{\mathbf{S}}\cdot\hat{\mathbf{n}}da$

**Radiation Pressure:**

perfectly absorbing: $P^{abs}_{\text{pressure}} = \frac{1}{c}\langle|\vec{\mathbf{S}}|\rangle$

perfectly reflecting: $P^{\text{ref}}_{\text{pressure}} = 2\frac{1}{c}\langle|\vec{\mathbf{S}}|\rangle$

Pressure and Force: $P_{\text{pressure}} = F/\text{A}$

**Stefan-Boltzmann Law**

Power $= \sigma\varepsilon AT^4$

$\sigma = 5.67\times10^{-8}\ \text{W}\cdot\text{m}^{-2}\cdot\text{K}^{-4}$

$\varepsilon =$ emissivity

**Interference**

$y_{max} = \dfrac{n\lambda L}{d}$

$y_{min} = \dfrac{(n+\frac{1}{2})\lambda L}{d}$

**Constants:**

$\varepsilon_0 \simeq 8.85\times10^{-12}\text{C}^2\cdot\text{N}^{-1}\cdot\text{m}^{-2}$

$\text{k}_e = 1/4\pi\varepsilon_0 \simeq 9.0\times10^9\,\text{N}\cdot\text{m}^2\cdot\text{C}^{-2}$

$\mu_0 \simeq 4\pi\times10^{-7}\text{C}^{-2}\cdot\text{N}\cdot\text{s}^2$

$c = 3.0\times10^8\ \text{m}\cdot\text{s}^{-1}$

**Circumferences, Areas, Volumes:**

The area of a circle of radius $r$ is $\pi r^2$. Its circumference is $2\pi r$.

The surface area of a sphere of radius $r$ is $4\pi r^2$ . Its volume is $(4/3)\pi r^3$.

The area of the side of a cylinder of radius $r$ and length $l$ is $2\pi rl$. Its volume is $\pi r^2 h$.

**Integration Table:**

$\int \dfrac{dx'}{a+x'} = \ln(a+x')$

$\int \dfrac{x'dx'}{(a^2+x'^2)^{3/2}} = \dfrac{-1}{(a^2+x'^2)^{1/2}}$

$\int \dfrac{dx'}{(a+x')^2} = \dfrac{-1}{(a+x')}$

$\int \dfrac{dx'}{(a^2+x'^2)^{3/2}} = \frac{1}{a^2}\dfrac{x'}{(a^2+x'^2)^{1/2}}$

$\int \dfrac{x'dx'}{(a^2+x'^2)^{1/2}} = (a^2+x'^2)^{1/2}$