1. **Análise Vetorial**

$$\begin{aligned}
\vec{A} &= A_x\,\vec{a}_x + A_y\,\vec{a}_y + A_z\,\vec{a}_z \text{ coord. retangulares}\\
\vec{A} &= A_\rho\,\vec{a}_\rho + A_\phi\,\vec{a}_\phi + A_z\,\vec{a}_z \text{ coord. cilíndricas}\\
\vec{A} &= A_r\,\vec{a}_r + A_\theta\,\vec{a}_\theta + A_\phi\,\vec{a}_\phi \text{ coord. esféricas}\\
\vec{A}\cdot\vec{B} &= |\vec{A}||\vec{B}|\,cos\,\theta_{AB} \quad \vec{A}\times\vec{B} = |\vec{A}||\vec{B}|\,sen\,\theta_{AB}\,\vec{a}_N\\
|\vec{A}| &= \sqrt{\vec{A}\cdot\vec{A}} \quad \vec{u}_A = \frac{\vec{A}}{|\vec{A}|}
\end{aligned}$$

coord. retangulares $\Longleftrightarrow$ coord. cilíndricas

$$\begin{aligned}
x &= \rho\,cos\,\phi \qquad y = \rho\,sen\,\phi \quad z = z\\
\rho &= \sqrt{x^2+y^2} \quad \phi = tan^{-1}\frac{y}{x} \quad z = z
\end{aligned}$$

	$\vec{a}_\rho$	$\vec{a}_\phi$	$\vec{a}_z$
$\vec{a}_x$	$cos\,\phi$	$-sen\,\phi$	0
$\vec{a}_y$	$sen\,\phi$	$cos\,\phi$	0
$\vec{a}_z$	0	0	1

coord. retangulares $\Longleftrightarrow$ coord. esféricas

$$\begin{aligned}
x &= r\,sen\,\theta\,cos\,\phi \qquad y = r\,sen\,\theta\,sen\,\phi \quad z = r\,cos\,\theta\\
r &= \sqrt{x^2+y^2+z^2} \quad \theta = cos^{-1}\frac{z}{\sqrt{x^2+y^2+z^2}}\\
\phi &= tan^{-1}\frac{y}{x}
\end{aligned}$$

	$\vec{a}_r$	$\vec{a}_\theta$	$\vec{a}_\phi$
$\vec{a}_x$	$sen\,\theta\,cos\,\phi$	$cos\,\theta\,cos\,\phi$	$-sen\,\phi$
$\vec{a}_y$	$sen\,\theta\,sen\,\phi$	$cos\,\theta\,sen\,\phi$	$cos\,\phi$
$\vec{a}_z$	$cos\,\theta$	$-sen\,\theta$	0

elementos diferenciais

coordenadas retangulares

$$dx,\ dy,\ dz,\ dv = dx\,dy\,dz \quad \vec{dl} = dx\,\vec{a}_x + dy\,\vec{a}_y + dz\,\vec{a}_z$$

coordernadas cilíndricas

$$d\rho,\ \rho\,d\phi,\ dz,\ dv = \rho\,d\rho\,d\phi\,dz \quad \vec{dl} = d\rho\,\vec{a}_\rho + \rho d\phi\,\vec{a}_\phi + dz\,\vec{a}_z$$

coordernadas esféricas

$$dr,\ rd\theta,\ rsen\theta d\phi, \quad dv = r^2\,sen\theta\,dr\,d\theta\,d\phi$$

$$\vec{dl} = dr\,\vec{a}_r + r\,d\theta\,\vec{a}_\theta + r\,sen\theta\,d\phi\,\vec{a}_\phi$$

divergência

coordenadas retangulares

$$\nabla\cdot\vec{D} = \frac{\partial D_x}{\partial x} + \frac{\partial D_y}{\partial y} + \frac{\partial D_z}{\partial z}$$

coordernadas cilíndricas

$$\nabla\cdot\vec{D} = \frac{1}{\rho}\frac{\partial}{\partial\rho}(\rho\,D_\rho) + \frac{1}{\rho}\frac{\partial D_\phi}{\partial\phi} + \frac{\partial D_z}{\partial z}$$

coordernadas esféricas

$$\nabla\cdot\vec{D} = \frac{1}{r^2}\frac{\partial}{\partial r}(r^2\,D_r) + \frac{1}{r\,sen\,\theta}\frac{\partial}{\partial\theta}(D_\theta\,sen\,\theta) + \frac{1}{r\,sen\,\theta}\frac{\partial D_\phi}{\partial\phi}$$

gradiente

coordenadas retangulares

$$\nabla V = \frac{\partial V}{\partial x}\,\vec{a}_x + \frac{\partial V}{\partial y}\,\vec{a}_y + \frac{\partial V}{\partial z}\,\vec{a}_z$$

coordenadas cilíndricas

$$\nabla V = \frac{\partial V}{\partial\rho}\,\vec{a}_\rho + \frac{1}{\rho}\frac{\partial V}{\partial\phi}\,\vec{a}_\phi + \frac{\partial V}{\partial z}\,\vec{a}_z$$

coordenadas esféricas

$$\nabla V = \frac{\partial V}{\partial r}\,\vec{a}_r + \frac{1}{r}\frac{\partial V}{\partial\theta}\,\vec{a}_\theta + \frac{1}{r\,sen\,\theta}\frac{\partial V}{\partial\phi}\,\vec{a}_\phi$$

rotacional

coordenadas retangulares

$$\begin{aligned}
\nabla\times\vec{H} &= \left(\frac{\partial H_z}{\partial y} - \frac{\partial H_y}{\partial z}\right)\vec{a}_x + \left(\frac{\partial H_x}{\partial z} - \frac{\partial H_z}{\partial x}\right)\vec{a}_y\\
&\quad + \left(\frac{\partial H_y}{\partial x} - \frac{\partial H_x}{\partial y}\right)\vec{a}_z
\end{aligned}$$

coordenadas cilíndricas

$$\begin{aligned}
\nabla\times\vec{H} &= \left(\frac{1}{\rho}\frac{\partial H_z}{\partial\phi} - \frac{\partial H_\phi}{\partial z}\right)\vec{a}_\rho + \left(\frac{\partial H_\rho}{\partial z} - \frac{\partial H_z}{\partial\rho}\right)\vec{a}_\phi\\
&\quad + \frac{1}{\rho}\left(\frac{\partial(\rho\,H_\phi)}{\partial\rho} - \frac{\partial H_\rho}{\partial\phi}\right)\vec{a}_z
\end{aligned}$$

coordenadas esféricas

$$\begin{aligned}
\nabla\times\vec{H} &= \frac{1}{r\,sen\,\theta}\left(\frac{\partial(H_\phi\,sen\,\theta)}{\partial\theta} - \frac{\partial H_\theta}{\partial\phi}\right)\vec{a}_r\\
&\quad + \frac{1}{r}\left(\frac{1}{sen\,\theta}\frac{\partial H_r}{\partial\phi} - \frac{\partial(r\,H_\phi)}{\partial r}\right)\vec{a}_\theta\\
&\quad + \frac{1}{r}\left(\frac{\partial(r\,H_\theta)}{\partial r} - \frac{\partial H_r}{\partial\theta}\right)\vec{a}_\phi
\end{aligned}$$

2. **Lei de Coloumb, Campo Elétrico e Lei de Gauss**

$$\begin{aligned}
\vec{F}_1 &= \frac{q_1\,q_2}{4\,\pi\,\varepsilon_0\,R_{12}^2}\,\vec{a}_{12} \quad \vec{E} = \frac{q}{4\,\pi\,\varepsilon_0\,R^2}\,\vec{a}_R\\
\vec{E} &= \sum_{m=1}^{n}\frac{q_m}{4\,\pi\,\varepsilon_0\,|\vec{r}-\vec{r}_m|^2}\,\vec{a}_m \quad \vec{E} = \int_l \frac{\rho_l\,dl'}{4\,\pi\,\varepsilon_0\,R^2}\,\vec{a}_R\\
\vec{E} &= \int_s \frac{\rho_s\,ds'}{4\,\pi\,\varepsilon_0\,R^2}\,\vec{a}_R \quad \vec{E} = \int_v \frac{\rho_v\,dv'}{4\,\pi\,\varepsilon_0\,R^2}\,\vec{a}_R\\
Q &= \int_l \rho_l\,dl \quad Q = \int_s \rho_s\,ds \quad Q = \int_v \rho_v\,dV\\
&\oint_s \vec{D}\cdot\vec{ds} = Q \quad \vec{D} = \int_v \frac{\rho_v\,dv'}{4\,\pi\,R^2}\,\vec{a}_R\\
&\nabla\cdot\vec{D} = \rho_v \quad \oint_s \vec{D}\cdot\vec{ds} = \int_v \nabla\cdot\vec{D}\,dv
\end{aligned}$$

3. **Energia e Potencial**

$$\begin{aligned}
W &= -q\int_{inicial}^{final}\vec{E}\cdot\vec{dl} \quad ddp = -\int_{inicial}^{final}\vec{E}\cdot\vec{dl}\\
V &= \int \frac{\rho_l\,dl}{4\,\pi\,\varepsilon_0\,R} \quad V = \int_s \frac{\rho_s\,ds}{4\,\pi\,\varepsilon_0\,R}\\
V &= \int_v \frac{\rho_v\,dv}{4\,\pi\,\varepsilon_0\,R} \quad \vec{E} = -\frac{dV}{dN}\vec{a}_N \quad \vec{E} = -\nabla V\\
W_E &= \frac{1}{2}\sum_{m=1}^{N} q_m\,V_m \quad W_E = \frac{1}{2}\int_v \rho_v\,V\,dv\\
W_E &= \frac{1}{2}\int_v \vec{D}\cdot\vec{E}\,dv \;=\; \frac{1}{2}\int_v \varepsilon_0|\vec{E}|^2\,dv
\end{aligned}$$

4. **Resistência, Material Dielétrico e Capacitância**

$$R = \frac{V_{ab}}{I} = \frac{-\int_b^a (\vec{E}\cdot\vec{dl})}{\int_s \sigma\,\vec{E}\cdot\vec{ds}} = \frac{-\int_b^a (\frac{\vec{J}}{\sigma}\cdot\vec{dl})}{\int_s \vec{J}\cdot\vec{ds}}$$

interface condutor-meio

$$D_t = E_t = 0 \quad D_n = \rho_s \quad E_n = \frac{\rho_s}{\varepsilon}$$

$$\rho_{sp} = \vec{P}\cdot\vec{n} \quad \rho_{vp} = \nabla\cdot\vec{P} \quad \oint_s \vec{P}\cdot\vec{ds} - \int_v \nabla\cdot\vec{P}\,dv = 0$$

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

$$\varepsilon_R = \frac{\varepsilon}{\varepsilon_0} \rightarrow \varepsilon_R = 1 + \chi_e \quad \vec{D} = \varepsilon\,\vec{E}$$

interface dielétrico-dielétrico

$$\frac{D_t^1}{D_t^2} = \frac{\varepsilon_1}{\varepsilon_2} \quad D_n^1 - D_n^2 = \rho_s \quad \varepsilon_1\,E_n^1 - \varepsilon_2\,E_n^2 = \rho_s$$

$$C = \frac{Q}{V} \quad C = \frac{\int_s \rho_s\,ds}{-\int_-^+ \vec{E}\cdot\vec{dl}} \quad C = \frac{\int_s \varepsilon\,\vec{E}\cdot\vec{ds}}{-\int_-^+ \vec{E}\cdot\vec{dl}} \quad C = \frac{2.0\,W_E}{V^2}$$

5. **Equação de Laplace e Poisson**

$$\nabla^2 V = -\frac{\rho}{\varepsilon} \qquad \nabla^2 V = 0$$

$$\nabla^2 V = \frac{\partial^2 V}{\partial^2 x} + \frac{\partial^2 V}{\partial^2 y} + \frac{\partial^2 V}{\partial^2 z} = 0$$

$$\nabla^2 V = \frac{1}{\rho}\frac{\partial}{\partial\rho}\left(\rho\frac{\partial V}{\partial\rho}\right) + \frac{1}{\rho^2}\frac{\partial^2 V}{\partial^2\phi} + \frac{\partial^2 V}{\partial^2 z} = 0$$

$$\nabla^2 V = \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial V}{\partial r}\right) + \frac{1}{r^2\,sen\,\theta}\frac{\partial}{\partial\theta}\left(sen\,\theta\,\frac{\partial V}{\partial\theta}\right) + \frac{1}{r^2\,sen^2\theta}\frac{\partial^2 V}{\partial^2\phi} = 0$$

solução produto em coordenadas retangulares

$$k_x^2 + k_y^2 + k_z^2 = 0$$

$$V(x,y,z) = (A\,x + B)\,(C\,e^{k_y\,y} + D\,e^{-k_y\,y})\,(E\,cosk_z z + F\,senk_z z)$$

solução produto em coordenadas cilíndricas

$$Z = A\,coshmz + B\,senhmz\ (m \neq 0) \quad Z = A\,z + B\ (m = 0)$$

$$F = A\,cosn\phi + B\,senn\phi\ (n \neq 0) \quad F = A\,\phi + B\ (n = 0)$$

$$R = A\,J_n(m\,\rho) + B\,Y_n(m\,\rho) \quad \text{para} \quad m \neq 0$$

$$R = A\,\rho^n + B\,\rho^{-n} \quad \text{para} \quad m = 0 \ \text{ e } \ n \neq 0$$

$$R = A\,ln\rho + B \quad \text{para} \quad m = n = 0$$

solução produto em coordenadas esféricas

$$G = A\,cosn\phi + B\,senn\phi \text{ para } n \neq 0 \quad G = A\,\phi + B \text{ para } n = 0$$

$$R = A\,r^m + B\,r^{-(m+1)} \qquad F = A\,P_m(cos\,\theta) + B\,Q_m(cos\,\theta)$$

$$P_0 = 1 \quad P_1 = cos\theta \quad P_2 = \frac{1}{2}\left(3\,cos^2\theta - 1\right)$$

$$P_3 = \frac{1}{2}\left(5\,cos^3\theta - 3\,cos\theta\right) \quad P_4 = \frac{1}{8}\left(35\,cos^4\theta - 30\,cos^2\theta + 3\right)$$

$$Q_0 = \frac{1}{2}\,ln\left(\frac{1+cos\theta}{1-cos\theta}\right) \quad Q_1 = \frac{cos\theta}{2}\,ln\left(\frac{1+cos\theta}{1-cos\theta}\right)$$

$$Q_2 = \frac{3\,cos^2\theta - 1}{4}\,ln\left(\frac{1+cos\theta}{1-cos\theta}\right) - \frac{3\,cos\theta}{2}$$

$$Q_3 = \frac{5\,cos^3\theta - 3\,cos\theta}{4}\,ln\left(\frac{1+cos\theta}{1-cos\theta}\right) - \frac{5\,cos^2\theta}{2} + \frac{2}{3}$$

$$F = A\,P_m^n(cos\,\theta) + B\,Q_m^n(cos\,\theta)$$

$$P_m^n(x) = (1-x^2)^{n/2}\frac{d^n P_m(x)}{d^n x} \quad Q_m^n(x) = (1-x^2)^{n/2}\frac{d^n Q_m(x)}{d^n x}$$

6. **Lei de Biot-Savart e Campo Magnético**

$$I = \frac{d\,q}{d\,t} \quad \vec{J} = \rho_v\,\vec{U} \quad \vec{J} = \rho_v^+\,\vec{U}_+ + \rho_v^-\,\vec{U}_- \quad I = \int_s \vec{J}\cdot\vec{ds}$$

$$\oint_s \vec{J}\cdot\vec{ds} = -\frac{d}{dt}\int_v \rho_v\,dv \quad \nabla\cdot\vec{J} = -\frac{\partial\rho}{\partial t} \quad I\,\vec{dl} \equiv \vec{J}_s\,ds \equiv \vec{J}_v\,dv$$

$$\vec{H} = \oint \frac{I\,\vec{dl}\times\vec{a}_R}{4\,\pi\,R^2} \quad \vec{H} = \int_s \frac{\vec{J}_s \times ds\vec{a}_R}{4\,\pi\,R^2} \quad \vec{H} = \int_v \frac{\vec{J}_v \times dv\vec{a}_R}{4\,\pi\,R^2}$$

$$\oint \vec{H}\cdot\vec{dl} = I \quad \nabla\times\vec{H} = \vec{J} \quad \oint_c \vec{H}\cdot\vec{dl} = \int_S \left(\nabla\times\vec{H}\right)\cdot d\vec{S}$$

$$\vec{B} = \mu\,\vec{H} \quad \Phi = \int_s \vec{B}\cdot d\vec{S} \quad \oint_s \vec{B}\cdot d\vec{S} = 0 \quad \nabla\cdot\vec{B} = 0$$

7. **Forças, Material Magnético e Indutância**

$$\vec{F} = \vec{F}_e + \vec{F}_m = q\,\left(\vec{E} + \vec{U}\times\vec{B}\right)$$

$$\vec{F} = \int_v \vec{J}_v\times\vec{B}\,dv \quad \vec{F} = \int_s \vec{J}_s\times\vec{B}\,ds \quad \vec{F} = \oint I\,\vec{dl}\times\vec{B}$$

$$\vec{F}_2 = \frac{\mu_0\,I_1\,I_2}{4\,\pi}\oint_{l_2}\left[\oint_{l_1}\frac{\vec{a}_{R_{12}}\times d\vec{l}_1}{R_{12}^2}\right]\times d\vec{l}_2$$

$$d\vec{T} = I\,\vec{ds}\times\vec{B} \quad d\vec{m} = I\,\vec{ds} \quad d\vec{T} = d\vec{m}\times\vec{B}$$

$$\vec{J}_{ms} = \vec{M}\times\vec{a}_n \quad \vec{J}_m = \nabla\times\vec{M} \quad \vec{H} = \frac{\vec{B}}{\mu_0} - \vec{M}$$

$$\vec{M} = X_m\,\vec{H} \quad \vec{B} = \mu_0\,\vec{H}\,(1+X_m) \quad \mu_r = 1+X_m \quad \vec{B} = \mu\,\vec{H}$$

interface magnética

$$B_{N1} = B_{N2} \quad H_{t1} - H_{t2} = J_s \quad \left(\vec{H}_1 - \vec{H}_2\right)\times\vec{a}_{N12} = \vec{J}_s$$

$$M_{t2} = \frac{X_{m2}}{X_{m1}}\,M_{t1} - X_{m2}\,J_s \quad \left(\frac{\vec{M}_1}{X_{m1}} - \frac{\vec{M}_2}{X_{m2}}\right)\times\vec{a}_{N12} = \vec{J}_s$$

$$L = \frac{\phi}{I} \quad M_{12} = \frac{N_1\,\phi_{12}}{i_1} \quad M_{21} = \frac{N_2\,\phi_{21}}{i_2}$$

$$W_H = \frac{1}{2}\int_v \vec{B}\cdot\vec{H}\,dv \quad L = \frac{2\,W_H}{I^2}$$

8. **Lei de Faraday e Corrente de Deslocamento**

$$fem = -\frac{d\phi}{dt}\ (V) \quad fem = -\frac{d}{dt}\int_s \vec{B}\cdot\vec{ds}$$

$$fem = -\int_s \frac{\partial\vec{B}}{\partial t}\cdot\vec{ds} + \oint\left(\vec{U}\times\vec{B}\right)\cdot\vec{dl}$$

9. **Equações de Maxwell**

$$\oint \vec{E}\cdot\vec{dl} = -\frac{d}{dt}\int_s \vec{B}\cdot\vec{ds} \qquad \nabla\times\vec{E} = -\frac{\partial\,\vec{B}}{\partial\,t}$$

$$\oint \vec{H}\cdot\vec{dl} = I + \frac{d}{dt}\int_s \vec{D}\cdot\vec{ds} \qquad \nabla\times\vec{H} = \vec{J} + \frac{\partial\,\vec{D}}{\partial\,t}$$

$$\oint \vec{D}\cdot\vec{ds} = \int_v \rho_v\,dv \qquad \nabla\cdot\vec{D} = \rho_v$$

$$\oint \vec{B}\cdot\vec{ds} = 0 \qquad \nabla\cdot\vec{B} = 0$$