

Luonnon vakioita:

Suure	Tunnus	Arvo	Yksikkö
Valonnopeus	c	299792458	m/s
Tyhjön permittiivisyys	μ_0	$4\pi \cdot 10^{-7}$	H/m
Tyhjön permeabiliteetti	ε_0	$8,8542 \cdot 10^{-12} \approx \frac{10^{-9}}{36\pi}$	F/m

Sähkömagnetiiikan kaavoja:

Liikkuvaan varaukseen kohdistuva voima	$F = q(\mathbf{U} \times \mathbf{B})$
Aineen sisäinen impedanssi	$\eta = \sqrt{\frac{\mu}{\varepsilon}}$
Hyvä johde	$\sigma \gg \omega\varepsilon$
Hyvä eriste	$\sigma \ll \omega\varepsilon$

Vektorimatematiikan kaavoja:

$$\mathbf{A} \cdot \mathbf{B} \times \mathbf{C} = \mathbf{B} \cdot \mathbf{C} \times \mathbf{A} = \mathbf{C} \cdot \mathbf{A} \times \mathbf{B}$$

$$\mathbf{A} \times (\mathbf{B} \times \mathbf{C}) = \mathbf{B}(\mathbf{A} \cdot \mathbf{C}) - \mathbf{C}(\mathbf{A} \cdot \mathbf{B})$$

$$\nabla(U + V) = \nabla U + \nabla V$$

$$\nabla \cdot (\mathbf{A} + \mathbf{B}) = \nabla \cdot \mathbf{A} + \nabla \cdot \mathbf{B}$$

$$\nabla \times (\mathbf{A} + \mathbf{B}) = \nabla \times \mathbf{A} + \nabla \times \mathbf{B}$$

$$\nabla \cdot (V\mathbf{A}) = (\nabla V) \cdot \mathbf{A} + V(\nabla \cdot \mathbf{A})$$

$$\nabla \times (V\mathbf{A}) = (\nabla V) \times \mathbf{A} + V(\nabla \times \mathbf{A})$$

$$\nabla \cdot (\mathbf{A} \times \mathbf{B}) = \mathbf{B} \cdot (\nabla \times \mathbf{A}) - \mathbf{A} \cdot (\nabla \times \mathbf{B})$$

$$\nabla \cdot (\nabla V) = \nabla^2 V$$

$$\nabla \times (\nabla \times \mathbf{A}) = \nabla(\nabla \cdot \mathbf{A}) - \nabla^2 \mathbf{A}$$

$$\nabla \times (\nabla V) = 0$$

$$\nabla \cdot (\nabla \times \mathbf{A}) = 0$$

$$\int_V \nabla \cdot \mathbf{A} dV = \oint_S \mathbf{A} \cdot d\mathbf{S} \quad (\text{Divergenssiteoreema})$$

$$\int_S \nabla \times \mathbf{A} \cdot d\mathbf{S} = \oint_C \mathbf{A} \cdot d\mathbf{l} \quad (\text{Stokesin teoreema})$$

Gradientti, divergenssi, roottori ja Laplacen operaattorit

Karteesisessa koordinaatistossa (x, y, z)

$$\nabla V = \frac{\partial V}{\partial x} \mathbf{e}_x + \frac{\partial V}{\partial y} \mathbf{e}_y + \frac{\partial V}{\partial z} \mathbf{e}_z$$

$$\nabla \cdot \mathbf{A} = \frac{\partial A_x}{\partial x} + \frac{\partial A_y}{\partial y} + \frac{\partial A_z}{\partial z}$$

$$\nabla \times \mathbf{A} = \begin{vmatrix} \mathbf{e}_x & \mathbf{e}_y & \mathbf{e}_z \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ A_x & A_y & A_z \end{vmatrix} = \left(\frac{\partial A_z}{\partial y} - \frac{\partial A_y}{\partial z} \right) \mathbf{e}_x + \left(\frac{\partial A_x}{\partial z} - \frac{\partial A_z}{\partial x} \right) \mathbf{e}_y + \left(\frac{\partial A_y}{\partial x} - \frac{\partial A_x}{\partial y} \right) \mathbf{e}_z$$

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

Sylinterikoordinaatistossa (ρ, φ, z)

$$\nabla V = \frac{\partial V}{\partial \rho} \mathbf{e}_\rho + \frac{1}{\rho} \frac{\partial V}{\partial \varphi} \mathbf{e}_\varphi + \frac{\partial V}{\partial z} \mathbf{e}_z$$

$$\nabla \cdot \mathbf{A} = \frac{1}{\rho} \frac{\partial}{\partial \rho} (\rho A_\rho) + \frac{1}{\rho} \frac{\partial A_\varphi}{\partial \varphi} + \frac{\partial A_z}{\partial z}$$

$$\nabla \times \mathbf{A} = \frac{1}{\rho} \begin{vmatrix} \mathbf{e}_\rho & \rho \mathbf{e}_\varphi & \mathbf{e}_z \\ \frac{\partial}{\partial \rho} & \frac{\partial}{\partial \varphi} & \frac{\partial}{\partial z} \\ A_\rho & \rho A_\varphi & A_z \end{vmatrix} = \left(\frac{\partial A_z}{\partial \varphi} - \frac{\partial A_\varphi}{\partial z} \right) \mathbf{e}_\rho + \left(\frac{\partial A_\rho}{\partial z} - \frac{\partial A_z}{\partial \rho} \right) \mathbf{e}_\varphi + \frac{1}{\rho} \left(\frac{\partial}{\partial \rho} (\rho A_\varphi) - \frac{\partial A_\rho}{\partial \varphi} \right) \mathbf{e}_z$$

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

Pallokoordinaatistossa (ρ, θ, φ)

$$\nabla V = \frac{\partial V}{\partial \rho} \mathbf{e}_\rho + \frac{1}{\rho} \frac{\partial V}{\partial \theta} \mathbf{e}_\theta + \frac{1}{\rho \sin \theta} \frac{\partial V}{\partial \varphi} \mathbf{e}_\varphi$$

$$\nabla \cdot \mathbf{A} = \frac{1}{\rho^2} \frac{\partial}{\partial \rho} (\rho^2 A_\rho) + \frac{1}{\rho \sin \theta} \frac{\partial}{\partial \theta} (A_\theta \sin \theta) + \frac{1}{\rho \sin \theta} \frac{\partial A_\varphi}{\partial \varphi}$$

$$\begin{aligned} \nabla \times \mathbf{A} &= \frac{1}{\rho^2 \sin \theta} \begin{vmatrix} \mathbf{e}_\rho & \rho \mathbf{e}_\theta & (\rho \sin \theta) \mathbf{e}_\varphi \\ \frac{\partial}{\partial \rho} & \frac{\partial}{\partial \theta} & \frac{\partial}{\partial \varphi} \\ A_\rho & \rho A_\theta & (\rho \sin \theta) A_\varphi \end{vmatrix} \\ &= \frac{1}{\rho \sin \theta} \left(\frac{\partial}{\partial \theta} (A_\varphi \sin \theta) - \frac{\partial A_\varphi}{\partial \varphi} \right) \mathbf{e}_\rho + \frac{1}{\rho} \left(\frac{1}{\sin \theta} \frac{\partial A_\rho}{\partial \varphi} - \frac{\partial}{\partial \rho} (\rho A_\varphi) \right) \mathbf{e}_\theta + \frac{1}{\rho} \left(\frac{\partial}{\partial \rho} (\rho A_\theta) - \frac{\partial A_\rho}{\partial \theta} \right) \mathbf{e}_\varphi \end{aligned}$$

$$\nabla^2 V = \frac{1}{\rho^2} \frac{\partial}{\partial \rho} \left(\rho^2 \frac{\partial V}{\partial \rho} \right) + \frac{1}{\rho^2 \sin \theta} \frac{\partial}{\partial \theta} \left(\sin \theta \frac{\partial V}{\partial \theta} \right) + \frac{1}{\rho^2 \sin^2 \theta} \frac{\partial^2 V}{\partial \varphi^2}$$