

$$\text{proton charge: } e = 1.602 \times 10^{-19} \text{ C}$$

$$\text{electron mass: } m_e = 9.11 \times 10^{-31} \text{ kg}$$

$$\varepsilon_0 = 8,854 \times 10^{-12} \text{ F m}^{-1}$$

$$F = ma$$

$$A_{\text{surface cylinder}} = \pi r^2 L$$

$$\text{electron charge: } -e$$

$$\text{proton mass: } m_p = 1.67 \times 10^{-27} \text{ kg}$$

$$\mu_0 = 4\pi \times 10^{-7} \text{ T m A}^{-1}$$

$$x = x_0 + v_0 t + \frac{1}{2} a t^2$$

$$A_{\text{surface sphere}} = 4\pi r^2$$

$$\varepsilon = -N \frac{d\Phi_B}{dt} \quad \left| \quad \oint_{\Gamma} \mathbf{E} \cdot d\mathbf{l} = -\frac{d\Phi_B}{dt} = -\frac{d}{dt} \int_S \mathbf{B} \cdot d\mathbf{S}$$

$$\varepsilon_{\text{ind}} = -L \frac{dI}{dt} \quad \left| \quad B_{\text{solen}} = \mu_0 \frac{N}{l} I$$

$$U_{B_{\text{inductor}}} = \frac{1}{2} L I^2 \quad \left| \quad L_{\text{solen}} = \mu_0 \frac{N^2}{l} \pi R^2$$

$$\mu = \mu_0 \mu_r$$

$$\mathbf{B} = \mu_r \mathbf{B}_0 = \mu \mathbf{H}$$

$$u_B = \frac{1}{2} \frac{B^2}{\mu} = \frac{1}{2} B H$$

$$\chi_m = \mu_r - 1$$

$$\mathbf{M} = \frac{\mathbf{B}}{\mu_0} - \mathbf{H} = \frac{\mu_r \mu_0 \mathbf{H}}{\mu_0} - \mathbf{H} = \underbrace{(\mu_r - 1)}_{\chi_m} \mathbf{H} = \chi_m \mathbf{H}$$

$$u_B = \frac{U_B}{\text{volume}}$$

$$\oint \mathbf{E} \cdot d\mathbf{S} = \frac{q}{\varepsilon_0}$$

$$\oint_{\Gamma} \mathbf{E} \cdot d\mathbf{l} = -\frac{d}{dt} \int_S \mathbf{B} \cdot d\mathbf{S}$$

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\varepsilon_0}$$

$$\text{rot } \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

$$\oint \mathbf{B} \cdot d\mathbf{S} = 0$$

$$\oint_{\Gamma} \mathbf{B} \cdot d\mathbf{l} = \mu_0 \int_S (\mathbf{j} + \varepsilon_0 \frac{\partial \mathbf{E}}{\partial t}) \cdot d\mathbf{S} = \mu_0 I + \varepsilon_0 \mu_0 \frac{d}{dt} \int_S \mathbf{E} \cdot d\mathbf{S}$$

$$\nabla \cdot \mathbf{B} = 0$$

$$\text{rot } \mathbf{B} = \mu_0 \mathbf{j} + \varepsilon_0 \mu_0 \frac{\partial \mathbf{E}}{\partial t}$$

$$\mathbf{D} = \varepsilon \mathbf{E}, \quad \mathbf{B} = \mu \mathbf{H}$$

$$\oint \mathbf{D} \cdot d\mathbf{S} = q$$

$$\oint_{\Gamma} \mathbf{E} \cdot d\mathbf{l} = -\frac{d}{dt} \int_S \mathbf{B} \cdot d\mathbf{S}$$

$$\nabla \cdot \mathbf{D} = \rho$$

$$\text{rot } \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

$$c = \frac{1}{\sqrt{\varepsilon_0 \mu_0}} \approx 3 \times 10^8 \text{ m s}^{-1}$$

$$\oint \mathbf{B} \cdot d\mathbf{S} = 0$$

$$\oint_{\Gamma} \mathbf{H} \cdot d\mathbf{l} = I + \frac{d}{dt} \int_S \mathbf{D} \cdot d\mathbf{S}$$

$$\nabla \cdot \mathbf{B} = 0$$

$$\text{rot } \mathbf{H} = \mathbf{j} + \frac{\partial \mathbf{D}}{\partial t}$$

$V(t) = V_0 \cos(\omega t); \quad I_0 = \frac{V_0}{ \tilde{Z} }$ R: $I(t) = \frac{V(t)}{R} = \frac{V_0}{R} \cos(\omega t)$ L: $V(t) = L \frac{dI}{dt} \longrightarrow I = \frac{V_0}{\omega L} \sin(\omega t) = \frac{V_0}{\omega L} \cos(\omega t - \frac{\pi}{2})$ C: $\begin{cases} V(t) = \frac{Q(t)}{C} \\ I = \frac{dQ(t)}{dt} \end{cases} \longrightarrow I = -\omega C V_0 \sin(\omega t) = \omega C V_0 \cos(\omega t + \frac{\pi}{2})$ Series: $\tilde{Z} = \tilde{Z}_1 + \tilde{Z}_2 + \dots$; Paralel: $\frac{1}{\tilde{Z}} = \frac{1}{\tilde{Z}_1} + \frac{1}{\tilde{Z}_2} + \dots$ R+L+C: $ \tilde{Z} = \sqrt{R^2 + (-\frac{1}{\omega C} + \omega L)^2}$ $\phi_{VI} = \arctan \frac{\text{Im} \tilde{Z}}{\text{Re} \tilde{Z}}; \quad \phi_{IV} = -\phi_{VI}$ R: $V_{\text{rms}} = \frac{V_0}{\sqrt{2}}; \quad I_{\text{rms}} = \frac{I_0}{\sqrt{2}}; \quad P_{\text{average_AC}} = R I_{\text{rms}}^2 \quad (P_{DC} = R I^2)$	Impedance $\tilde{Z}$ R $i\omega L$ $\frac{1}{i\omega C} = -\frac{i}{\omega C}$ $f_r = \frac{1}{2\pi\sqrt{LC}}$	Reactance χ ωL $\frac{1}{\omega C}$
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$p = \frac{F}{A}$ $p = Z \frac{u \text{ or } S}{c} \begin{cases} Z = 1 & \text{totally absorbed} \\ Z = 2 & \text{totally reflected} \\ 1 < Z < 2 & \text{intermediate case} \end{cases}$ $\mathbf{S} = \mathbf{E} \times \mathbf{H}$	$S = \frac{Pot}{A}$ $F = \frac{P}{t}, P \text{ is linear momentum}$ $\longrightarrow P = Z \frac{\overbrace{S A t}^u}{c} = Z \frac{U}{c}$
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Volumetric density of the linear momentum of the electromagnetic field : $\varepsilon_0 \mathbf{E} \times \mathbf{B} = \varepsilon_0 \mathbf{E} \times (\mu_0 \mathbf{H}) = \varepsilon_0 \mu_0 \mathbf{S}$

linear momentum of the electromagnetic field in a volume V : $\int_V \varepsilon_0 \mathbf{E} \times \mathbf{B} \, dV = \int_V \varepsilon_0 \mu_0 \mathbf{S} \, dV$

Poynting's theorem: $-\frac{d}{dt} \left[\int_V \left(\frac{\varepsilon E^2}{2} + \frac{B^2}{2\mu} \right) dV \right] = \int_V \mathbf{j} \cdot \mathbf{E} \, dV + \oint_S (\mathbf{E} \times \mathbf{H}) \cdot d\mathbf{S}$

$\mathbf{B} = \nabla \times \mathbf{A}$ $\Phi_B = \int_S \mathbf{B} \cdot d\mathbf{S} = \int_S (\nabla \times \mathbf{A}) \cdot d\mathbf{S} = \oint_{\Gamma} \mathbf{A} \cdot d\mathbf{l}$	$\mathbf{E} = -\nabla \varphi - \frac{\partial \mathbf{A}}{\partial t}$
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$\xi(x, t) = \xi_0 \sin[k(x - vt) + \varphi_0]$ $k = \frac{2\pi}{\lambda}; \quad v = \frac{\lambda}{T} = \lambda f$ $v = \frac{\omega}{k}; \quad \omega = 2\pi f$ $\nabla^2 \mathbf{B} = \mu\sigma \frac{\partial \mathbf{B}}{\partial t} + \varepsilon\mu \frac{\partial^2 \mathbf{B}}{\partial t^2}$ $Q = \frac{\omega\varepsilon}{\sigma}$ $v = \frac{\omega}{\omega\sqrt{\frac{\varepsilon\mu}{2}(\sqrt{1+\frac{1}{Q^2}}+1)^{1/2}}} = \left(\frac{2}{\sqrt{1+\frac{1}{Q^2}}+1} \right)^{1/2} \frac{1}{\sqrt{\varepsilon\mu}}$	$\xi(x, t) = \xi_0 \sin(kx - \omega t + \varphi_0)$ $\xi(\mathbf{r}, t) = \xi_0 \sin(\mathbf{k} \cdot \mathbf{r} - \omega t + \varphi_0)$ $\bar{S} = \frac{E_0 B_0}{2\mu}; \quad E_0 = c B_0$ $\nabla^2 \mathbf{E} = \mu\sigma \frac{\partial \mathbf{E}}{\partial t} + \varepsilon\mu \frac{\partial^2 \mathbf{E}}{\partial t^2}$ $\Delta = \frac{1}{\omega\sqrt{\frac{\varepsilon\mu}{2}(\sqrt{1+\frac{1}{Q^2}}-1)^{1/2}}}$ $\Omega = \arctan(\sqrt{Q^2+1} - Q) = \arctan \frac{1}{\sqrt{Q^2+1+Q}}$
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