$\lambda = \frac{c}{f}$, if $d < \frac{\lambda}{10} \Rightarrow I$ instant.

$I = \frac{\Delta Q}{\Delta t}$ $\quad P = I \cdot V = I^2 R = \frac{V^2}{R}$

$I = \frac{V}{R}$ $\quad R = \rho \cdot \frac{l}{A}$

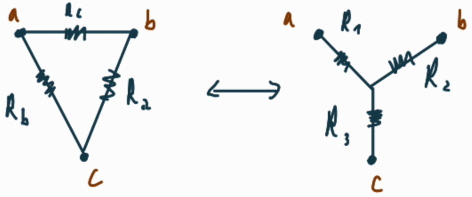
$\frac{1}{R_{eq\parallel}} = \sum \frac{1}{R_i}$ $\quad R_{eq\,series} = \sum R_i$

KCL: $\sum I_i = 0$ in a node

KVL: $\sum V_i = 0$ in a loop

R in series, for R_i: $V_i = \frac{R_i}{\sum R_j} \cdot V$

2 R in paralel: $I_1 = \frac{R_2}{R_1 + R_2}(I_1 + I_2)$



$P = R_1R_2 + R_2R_3 + R_1R_3$

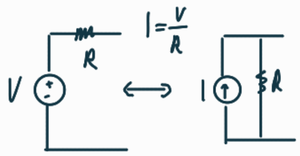
$S = R_a + R_b + R_c$

$R_1 = \frac{R_bR_c}{S}$ $\quad R_2 = \frac{R_aR_c}{S}$ $\quad R_3 = \frac{R_aR_b}{S}$

$R_a = \frac{P}{R_1}$ $\quad R_b = \frac{P}{R_2}$ $\quad R_c = \frac{P}{R_3}$

NVM: KCL equations in nodes $\quad$ MCM: KVL equations in meshes

source tranformation:



for max power: $R_L = R_{Th}$

$p = \frac{V_{Th}^2}{4R_{Th}}$

Thévenin 1) only independent sources

- short V $\quad$ - open C
- calculate $R_{Th} = R_{eq}$

Thévenin 2) otherwise:

- deactivate independent sources like in 1)
- apply test C/V then calculate the other one; $R_{Th} = \frac{V_T}{I_T}$

$V = L\frac{di}{dt}$

$w = \frac{1}{2} I^2 L$

$p = i \cdot V = i \cdot L \cdot \frac{di}{dt}$

$I = C\frac{dv}{dt}$

$w = \frac{1}{2} C V^2$

$p = V \cdot i = v \cdot C \cdot \frac{dv}{dt}$

average power: $p = \frac{1}{2} R \cdot I^2$

$M = \sqrt{L_1 \cdot L_2}$ coupling coeff.

$w = 2\pi f$

$L_{eq\,series} = \sum L_i$ $\quad \frac{1}{L_{eq\parallel}} = \sum \frac{1}{L_i}$ $\quad Z_L = j\omega L$

$\frac{1}{C_{eq\,series}} = \sum \frac{1}{C_i}$ $\quad C_{eq\parallel} = \sum C_i$ $\quad Z_C = \frac{1}{j\omega C}$ $\quad \frac{1}{j} = -j$

$\rho e^{i\theta} = \rho(\cos\theta + i\sin\theta)$ $\quad i(t) = i_0\cos(\omega t + \theta) = i\angle\theta$ $\quad V(t) = V_0\cos(\omega t + \theta) = V\angle\theta$

RL: $\tau = \frac{L}{R}$ natural resp.: $i(t) = i_0 \cdot e^{-\frac{t}{\tau}}$ step resp.: $i(t) = \frac{V_s}{R} + \left(i_0 - \frac{V_s}{R}\right)e^{-\frac{t}{\tau}}$ $\quad v(t) = (V_s - IR)e^{-\frac{t}{\tau}}$

RC: $\tau = RC$ natural resp: $v(t) = V_0 e^{-\frac{t}{\tau}}$ step resp.: $i(t) = \left(i_s - \frac{V_0}{R}\right)e^{-\frac{t}{\tau}}$ $\quad v(t) = V_s + (V_0 - V_s)e^{-\frac{t}{\tau}}$

RLC: $\quad s^2 + 2\alpha s + \omega_0^2 = 0$ $\quad$ C & L in $\parallel \Rightarrow \alpha = \frac{1}{2RC}$ $\quad \alpha > \omega_0$ overdamped

$\omega_0 = \frac{1}{\sqrt{LC}}$ $\quad s_{1,2} = -\alpha \pm \sqrt{\alpha^2 - \omega_0^2}$ $\quad$ C & L in series $\Rightarrow \alpha = \frac{R}{2L}$ $\quad \alpha < \omega_0$ underdamped

$\alpha = \omega_0$ critically damped

natural resp: $\quad$ parallel: $x(t) = v(t)$ | series $x(t) = i_L(t) = i_C(t)$

over: $x(t) = A_1e^{s_1t} + A_2e^{s_2t}$ $\quad x(0) = A_1 + A_2$ $\quad x'(0) = A_1s_1 + A_2s_2$

under: $x(t) = (B_1\cos(\omega_dt) + B_2\sin(\omega_dt))e^{-\alpha t}$ $\quad \omega_d = \sqrt{\omega_0^2 - \alpha^2}$ $\quad x(0) = B_1$ $\quad x'(0) = -\alpha B_1 + \omega_d B_2$

crit: $x(t) = (D_1t + D_2)e^{-\alpha t}$ $\quad X(0) = D_2$ $\quad x'(0) = D_1 - \alpha D_2$

step resp: $\quad$ parallel: $x(t) = i_L(t)$ | series: $x(t) = V_C(t)$ $\quad x_f = x(\infty)$

over: $x(t) = x_f + A_1e^{s_1t} + A_2e^{s_2t}$ $\quad x(0) = x_f + A_1 + A_2$ $\quad x'(0) = A_1s_1 + A_2s_2$

under: $x(t) = x_f + (B_1\cos\omega_dt + B_2\sin\omega_dt)e^{-\alpha t}$ $\quad x(0) = x_f + B_1$ $\quad x'(0) = -\alpha B_1 + \omega_d B_2$

crit: $x(t) = x_f + (D_1 + D_2)e^{-\alpha t}$ $\quad x(0) = x_f + D_2$ $\quad x'(0) = D_1 - \alpha D_2$

Energy in RL: $\frac{1}{2}L_1i_1^2 + \frac{1}{2}L_2i_2^2 + \ldots + Mi_1i_2 + \ldots$

Volume charge density: ρ

Current: I ; E potential: V

Volume current density: $\vec{J}$

Electric field intensity: $\vec{E}$

Electric flux density: $\vec{D}$

Magnetic field intensity: $\vec{H}$

Magnetic flux density: $\vec{B}$

M potential: A

ES: Gauss law: $\oint E\,dS = \frac{Q_{int}}{\varepsilon_0}$

no MF: $\begin{cases} \nabla \times \vec{E} = 0 \\ \nabla \cdot \vec{E} = \frac{\rho}{\varepsilon_0} \end{cases} \Leftrightarrow \begin{matrix} \oint_c E \cdot dl = 0 \\ \oint_s E \cdot ds = \frac{Q}{\varepsilon_0} \end{matrix}$

Coulomb's law: $\vec{F} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{q_1 q_2}{R^2}$

$\vec{E} = -\nabla V$; Joules: $P = \int_v (\vec{E} \cdot \vec{J})\,dv$

Ohm: micro $\vec{J} = \sigma \vec{E}$, macro: $I = \frac{V}{R}$

equation of continuity: $\nabla \cdot \vec{J} = -\frac{\partial \rho}{\partial t}$

MS: Ampere's law: $\frac{1}{\mu_0} \oint_{\partial s} B\,dl = I$

Gauss law: $\oint B\,dS = 0$, solenoid wtf: $B = \mu_0 n I$

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

$\nabla \times \vec{B} = \mu_0 \vec{J}$ $\rightarrow$ | Poisson: $\nabla^2 A = -\mu_0 \vec{J} \rightarrow \nabla^2 V = -\frac{\rho}{\varepsilon}$

| Biot-Savart: $B = \int_c \vec{dB}$

M dipole moment: $\vec{m} = \vec{a}_m I S$, self inductance $L_{11}: \frac{\Lambda_{11}}{I_1}$

M energy: $W = \frac{1}{2} \sum_{k=1}^{n} I_k \Phi_k$; $W_m = \frac{1}{2} \int_v (\vec{A} \cdot \vec{J})\,dv$; M force: $F_m = I \oint_c d\vec{l} \times \vec{B}$

Maxwell: ES/MS independent

integral:

$\oint_S \vec{D}\,d\vec{s} = Q_{encl.}$

$\oint_C \vec{E} \cdot d\vec{l} = 0$

$\oint \vec{B} \cdot d\vec{s} = 0$

$\oint_C \vec{H} \cdot d\vec{l} = I_{encl.}$

diff:

$\nabla \cdot \vec{D} = \rho_v$

$\nabla \times \vec{E} = 0$

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

$\nabla \times \vec{H} = \vec{J}$

Time varying (dynamic)

$\oint_S \vec{D}\,d\vec{s} = Q_{encl.}$

$\oint_c \vec{E} \cdot d\vec{l} = -\int_s \frac{\partial \vec{B}}{\partial t} \cdot d\vec{s}$

$\oint_S \vec{B} \cdot d\vec{s} = 0$

$\oint_c \vec{H} \cdot d\vec{l} = I_{encl.} + \int_s \frac{\partial}{\partial t} \vec{D} \cdot d\vec{s}$

$\nabla \cdot \vec{D} = \rho_v$

$\nabla \times \vec{E} = -\frac{\partial}{\partial t} \vec{B}$

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

$\nabla \times \vec{H} = \vec{J} + \frac{\partial}{\partial t} \vec{D}$ where: $\nabla \cdot \vec{J} = -\frac{\partial \rho}{\partial t}$

gradient: $\nabla V = \vec{a} \cdot \frac{dV}{dn}$

divergence: $\nabla \cdot \vec{A} = \lim_{\Delta v \to 0} \frac{\oint_s \vec{A}\,ds}{\Delta v} \Rightarrow \oint_s \vec{A}\,d\vec{s} = \int_v (\nabla \cdot \vec{A})\,dv$

div. th.

curl: $\nabla \times \vec{A} = \lim_{\Delta s \to 0} \frac{\vec{a}_n (\oint_{C_{max}} \vec{A}\,d\vec{l})}{\Delta s}$

Stoke's theorem: $\nabla \times \vec{A} = \lim_{\Delta s \to 0} \frac{\vec{a}_n (\oint_{C_{max}} \vec{A}\,d\vec{l})}{\Delta s} \Rightarrow$

$\Rightarrow \oint_c \vec{A}\,d\vec{l} = \int_s (\nabla \times \vec{A})\,d\vec{s}$

scalar Laplacian: $\nabla^2 V = \nabla(\nabla V) = \frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} + \frac{\partial^2 V}{\partial z^2}$

vector Laplacian: $\nabla^2 \vec{A} = \nabla(\nabla \vec{A}) - \nabla \times \nabla \times \vec{A} = \vec{a}_x(\nabla^2 A_x) + \vec{a}_y(\nabla^2 A_y) + \vec{a}_z(\nabla^2 A_z)$

conservative V.F.: $\nabla \times (\nabla V) = 0$ ES potential

solenoidal: $\nabla \cdot (\nabla \times \vec{A}) = 0$ MS potential

Hemholtz: 59, 58

Faraday's law: $\oint_c \vec{E} \cdot d\vec{l} = -\int_s \frac{\partial \vec{B}}{\partial t} \cdot d\vec{S}$ or $\nabla \times \vec{E} = \frac{\partial \vec{B}}{\partial t}$

modified Ampere: $\nabla \times \vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t}$

Homogeneous Maxwell:

$\nabla \times \vec{E} = -\mu \frac{\partial \vec{H}}{\partial t}$

$\nabla \times \vec{H} = \varepsilon \frac{\partial \vec{E}}{\partial t}$

$\nabla \cdot \vec{E} = 0$

$\nabla \cdot \vec{H} = 0$

$\frac{\partial}{\partial t} = j\omega$ $\Rightarrow$

$\nabla \times \vec{E} = -j\omega\mu \vec{H}$

$\nabla \times H = j\omega\varepsilon \vec{E}$

$\nabla \cdot \vec{E} = 0$

$\nabla \cdot \vec{H} = 0$

$\nabla^2 \vec{E} - \mu\varepsilon \frac{\partial^2 \vec{E}}{\partial t^2} = 0$

$\nabla^2 \vec{H} - \mu\varepsilon \frac{\partial^2 \vec{H}}{\partial t^2} = 0$

E.M. wave propagatition

potentials (timevarying): $\vec{E} = -\nabla V - \frac{\partial \vec{A}}{\partial t}$

$\nabla^2 \vec{A} - \mu\varepsilon \frac{\partial^2 \vec{A}}{\partial t^2} = -\mu \vec{J}$

$\nabla^2 V - \mu\varepsilon \frac{\partial^2 V}{\partial t^2} = -\frac{\rho}{\varepsilon}$

$\vec{B} = \nabla \times \vec{A}$