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Lightspeed, max. group velocity :

$$\begin{aligned} c &= \frac{|\mathcal{E}|}{|\mathcal{B}|} = \frac{1}{\sqrt{\epsilon_0 \mu_0}} \left[ \frac{F_{\mathcal{B}}}{F_{\mathcal{E}}} \right] = \frac{1}{\sqrt{\epsilon_0 \mu_0}} = \frac{\eta}{\sqrt{\epsilon \mu}} = \frac{\eta}{\sqrt{\epsilon_0 \epsilon_r \mu_0 \mu_r}} = \\ \eta \cdot c_{ph} &= \sqrt{v_{phase} \cdot v_{matter}} = \\ \frac{\omega}{k} &= \frac{\lambda}{\mathcal{J}} = \nu \lambda = -\frac{d\lambda}{d\nu} \nu^2 = \lambda^2 \frac{\mathcal{J}_\lambda}{\mathcal{J}_\nu} = \frac{\langle |\mathcal{S}| \rangle}{\langle w_{EM} \rangle} = v_{gr}^{max} \\ &\leq v_{ph} - \lambda \frac{d}{d\lambda} v_{ph} = \frac{d}{dk} \omega = v_{gr} \end{aligned} \tag{1}$$

where:

$F_{\mathcal{E}} = q\mathcal{E} \equiv$  Coulomb-Force (Electric, charge presence, localization in space)

$F_{\mathcal{B}} = q(v \times \mathcal{B}) \equiv$  Lorentz-Force (Magnetic, charge movement, localization in time)

$\left[ \frac{F_{\mathcal{B}}}{F_{\mathcal{E}}} \right] = 1$

$\mathcal{J} \equiv$  Flux Density

$\mathcal{S} \equiv$  Poynting-Vector, Intensity

$w_{EM} \equiv$  Energy Density ElectroMagnetic

$\eta \equiv$  [Refraction Index](#)

Refraction for identifying matter (property of matter):

$$\begin{aligned} \eta &\stackrel{opt.}{=} \frac{\sin(\alpha)}{\sin(\beta)} = \frac{\eta_\beta}{\eta_\alpha} \stackrel{prism}{=} \frac{\sin[\frac{1}{2}(\varpi + \varsigma_{min})]}{\sin[\frac{1}{2}\varpi]} \\ &\stackrel{phys.}{=} \sqrt{\epsilon_r \mu_r} = \frac{\lambda_\alpha}{\lambda_\beta} = \frac{v_{ph,\alpha}}{v_{ph,\beta}} = \frac{1}{2} \frac{\lambda}{d_r} \frac{n}{\cos(\beta)} = \sqrt{\left( \frac{n}{2} \frac{\lambda}{d_r} \right)^2 + \sin(\alpha)^2} \\ &\stackrel{dispersion}{=} \eta(\lambda) = \eta(\omega) \stackrel{anisotropy}{=} \eta(r) \end{aligned} \tag{2}$$

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$$\text{Vacuum} \iff \eta = 1f = \text{FocalLength} \quad D = \text{RefractivePower}(\text{dioptry})$$

$n \equiv \text{order ("quantum cycle")}$ :

$$n = \frac{\nu}{c} \Delta s = \frac{\Delta \varphi}{2\pi} = 2\eta \frac{d_r}{\lambda} \sqrt{\eta^2 - \sin(\alpha)^2} = 2\eta \frac{d_r}{\lambda} \cos(\beta) = \frac{q}{e_0} \in \mathbb{N} \quad (3)$$

$$v^2 = \left( \frac{\nu \lambda}{\eta} \right)^2 = \left( \frac{\omega}{k\eta} \right)^2$$

$$\left( \frac{\eta}{c} \right)^2 = \epsilon \mu \quad \epsilon = \epsilon_0 \epsilon_r \quad \mu = \mu_0 \mu_r$$

where:

$\{\alpha, \beta\} := \text{radiation orientation angles}$

$d_r = r_{x+1} - r_x := \text{distance in space}$

$\alpha := \text{irradiation angle, incoming radiation direction, from source/sender (Einstrahlungswinkel zur Normalen auf Grenzfläche des Mediums)}$

$\beta := \text{refraction angle for bent transmitted radiation } A_t \text{ orientation in matter (Durchstrahlungswinkel zur Normalen aus Grenzfläche ins Medium)}$

$\epsilon_0 := \text{Dielectric Constant (conductiv electric charge)}$

$\mu_0 := \text{Magnetic Constant (permeability in vacuum)}$