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Velocity - Movement of Matter in Space and Time

Matter and Vacuum - Refraction, max. phase velocity, max. group velocity:

Lightspeed, group velocity max.:

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

where:

\mathcal{J} \equiv Flux Density flow ¹

\mathcal{S} \equiv Poynting-Vector intensity

w_{EM} \equiv Energy Density electromagnetic

Refraction Index:

Refraction for identifying matter (property of matter):

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

Vacuum $\Leftrightarrow \eta = 1$: [1]

$$f = FocalLength \quad D = RefractivePower(dioptry) \tag{3}$$

¹Flux Density

$n \equiv$ order (“quantum”):

$$n = \frac{\nu}{c} \Delta s = \frac{\Delta\varphi}{2\pi} = 2\eta \frac{d_l}{\lambda} \sqrt{\eta^2 - \sin(\alpha)^2} = 2\eta \frac{d_l}{\lambda} \cos(\beta) = \frac{q}{e_0} \quad \in \mathbb{N} \quad (4)$$

$$v^2 = \left(\frac{\nu\lambda}{\eta} \right)^2 = \left(\frac{\omega}{k\eta} \right)^2 \quad (5)$$

$$\left(\frac{\eta}{c} \right)^2 = \epsilon\mu \quad \epsilon = \epsilon_0\epsilon_r \quad \mu = \mu_0\mu_r \quad (6)$$

where:

d_l := distance length

α := irradiation angle, incoming radiation direction, from source/sender (Einstrahlungswinkel zur Normalen auf Grenzfläche des Mediums)

β := refraction angle for bended transmitted radiation A_t orientation in matter (Durchstrahlungswinkel zur Normalen aus Grenzfläche ins Medium)

[1] Brechkraft