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### Velocity - Movement of Matter in Space and Time

### Matter and Vacuum - Refraction, max. Phasevelocity

Lightspeed, Groupvelocity max.:

$$\begin{aligned} c &= \frac{1}{\sqrt{\epsilon_0 \mu_0}} = \frac{|\mathcal{E}|}{|\mathcal{B}|} = \frac{\omega}{k} = \frac{\lambda}{\mathcal{T}} = \nu \lambda = -\frac{d\lambda}{d\nu} \nu^2 \\ &= \lambda^2 \frac{\mathcal{J}_\lambda}{\mathcal{J}_\nu} = \frac{\langle |\mathcal{S}| \rangle}{\langle w_{EM} \rangle} = v_{gr}^{max} \leq v_{ph} - \lambda \frac{d}{d\lambda} v_{ph} = \frac{d}{dk} \omega = v_{gr} \end{aligned} \quad (1)$$

$$c_{ph} = \frac{c}{\eta}$$

where:

$\mathcal{J} \equiv$  Flux Density

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

$w_{EM} \equiv$  Energy Densitix ElectroMagnetic

$$c^2 = v_{phase} \cdot v_{matter} = \epsilon \mu \eta^2 = \epsilon_0 \epsilon_r \mu_0 \mu_r \eta^2$$