Relationship of acoustic quantities associated with a plane progressive acoustic sound wave

Deutsch: Zusammenhang der akustischen Größen http://www.sengpielaudio.com/ZusammenhangDerAkustischenGroessen.pdf

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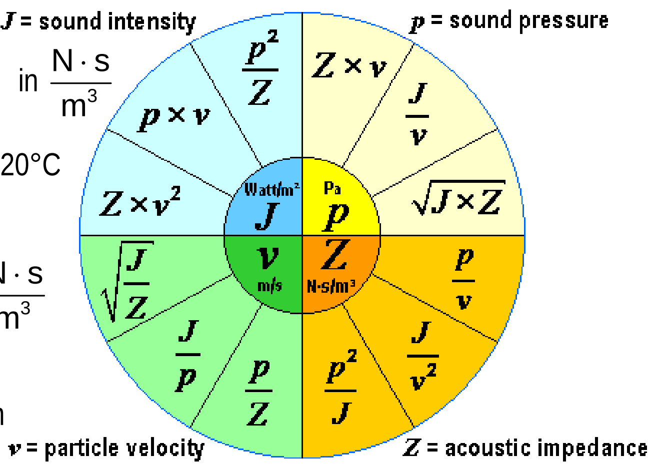
Acoustic quantities	ξ	v	a	p	I	E	P_{ac}
Particle displacement ξ	–	$\frac{v}{\omega}$	$\frac{a}{\omega^2}$	$\frac{p}{\omega \cdot Z}$	$\frac{1}{\omega}\sqrt{\frac{I}{Z}}$	$\frac{1}{\omega}\sqrt{\frac{E}{\rho}}$	$\frac{1}{\omega}\sqrt{\frac{P_{ac}}{Z \cdot A}}$
Particle velocity v	$\xi \cdot \omega$	–	$\frac{a}{\omega}$	$\frac{p}{Z}$	$\sqrt{\frac{I}{Z}}$	$\sqrt{\frac{E}{\rho}}$	$\sqrt{\frac{P_{ac}}{Z \cdot A}}$
Particle acceleration a	$\xi \cdot \omega^2$	$v \cdot \omega$	–	$\frac{p \cdot \omega}{Z}$	$\omega\sqrt{\frac{I}{Z}}$	$\omega\sqrt{\frac{E}{\rho}}$	$\omega\sqrt{\frac{P_{ac}}{Z \cdot A}}$
Sound pressure p	$\xi \cdot \omega \cdot Z$	$v \cdot Z$	$\frac{a \cdot Z}{\omega}$	–	$\sqrt{I \cdot Z}$	$c\sqrt{\rho \cdot E}$	$\sqrt{\frac{P_{ac} \cdot Z}{A}}$
Sound intensity $I = P_{ac} / A = p \cdot v$	$\xi^2 \cdot \omega^2 \cdot Z$	$v^2 \cdot Z$	$\frac{a^2 \cdot Z}{\omega^2}$	$\frac{p^2}{Z}$	–	$E \cdot c$	$\frac{P_{ac}}{A}$
Sound energy density E or w	$\xi^2 \cdot \omega^2 \cdot \rho$	$v^2 \cdot \rho$	$\frac{a^2 \cdot \rho}{\omega^2}$	$\frac{p^2}{Z \cdot c}$	$\frac{I}{c}$	–	$\frac{P_{ac}}{c \cdot A}$
Sound power $P_{ac} = I \cdot A$	$\xi^2 \cdot \omega^2 \cdot Z \cdot A$	$v^2 \cdot Z \cdot A$	$\frac{a^2 \cdot Z \cdot A}{\omega^2}$	$\frac{p^2 \cdot A}{Z}$	$I \cdot A$	$E \cdot c \cdot A$	–

White = linear sound field size and gray = squared sound energy size.



Specific acoustic impedance $Z = \rho \cdot c = \frac{p}{v} = \frac{I}{v^2} = \frac{p^2}{I}$ in $\frac{\text{N} \cdot \text{s}}{\text{m}^3}$

Density of air ρ in $\frac{\text{kg}}{\text{m}^3}$ is 1.204 kg/m³ at 20°C

Angular frequency $\omega = 2 \cdot \pi \cdot f$

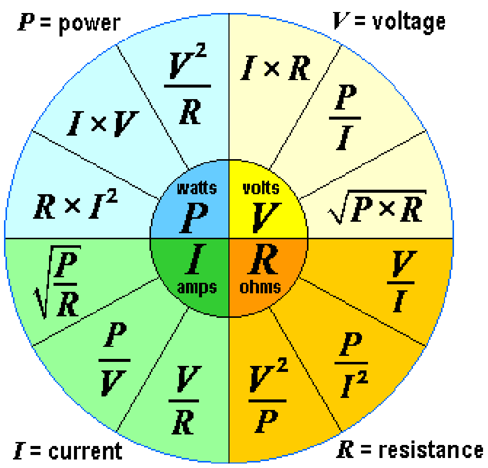
Frequency f in Hz = $\frac{1}{\text{s}}$ in air of 20°C: $Z = 413 \; \frac{\text{N} \cdot \text{s}}{\text{m}^3}$

Area through a unit area normal to the direction A in m^2

Displacement of air particles (excursion amplitude) ξ in m

Particle velocity (velocity amplitude) $v = s/t$ in $\frac{\text{m}}{\text{s}}$

To the comparison:



Particle acceleration $a = F/m$ in $\frac{\text{m}}{\text{s}^2}$

Sound pressure (excess pressure) $p = \frac{F}{A}$ in $\frac{\text{N}}{\text{m}^2} = \text{Pa}$

Sound intensity I or $J = p \cdot v = \frac{P_{ac}}{A}$ in $\frac{\text{W}}{\text{m}^2}$

Sound energy density E or $w = \frac{I}{c}$ in $\frac{\text{W} \cdot \text{s}}{\text{m}^3}$

Here is 1 Joule J = W · s = N · m

Sound power $P_{ac} = I \cdot A$ in W

Speed of sound c in m/s (at 20°C is c = 343 m/s)

Because 1 W × s = 1 N × m, the sound energy density is 1 W × s / m³ ≡ 1 N·m / m³ = 1 N / m² and that is the unit of a sound pressure in pascals! To remember: W × s = N × m = J (joule).