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

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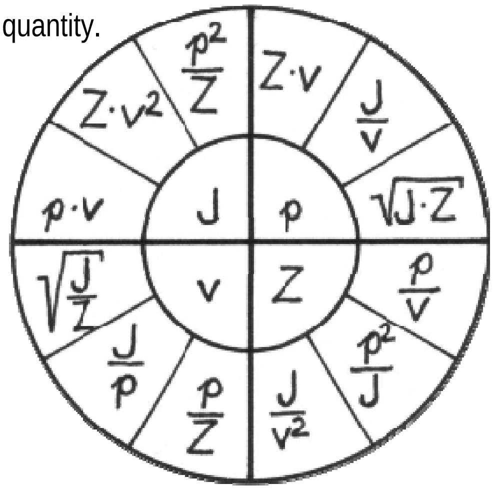
| | $\xi$ | $v$ | $a$ | $p$ | $I$ | $E$ | $P_{ac}$ |
|---|---|---|---|---|---|---|---|
| Particle displacement $\xi$ | – | $\frac{v}{\omega}$ | $\frac{a}{\omega^2}$ | $\frac{p}{\omega \cdot Z}$ | $\frac{1}{\omega}\sqrt{\frac{I}{Z}}$ | $\frac{1}{\omega}\sqrt{\frac{E}{\rho}}$ | $\frac{1}{\omega}\sqrt{\frac{P_{ac}}{Z \cdot A}}$ |
| 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 accelera-tion $a$ | $\xi \cdot \omega^2$ | $v \cdot \omega$ | – | $\frac{p \cdot \omega}{Z}$ | $\omega\sqrt{\frac{I}{Z}}$ | $\omega\sqrt{\frac{E}{\rho}}$ | $\omega\sqrt{\frac{P_{ac}}{Z \cdot A}}$ |
| 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 quantity and gray = squared sound energy quantity.




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 $\rho$ in $\frac{\text{kg}}{\text{m}^3}$ is 1.204 kg/m³ at 20 °C

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

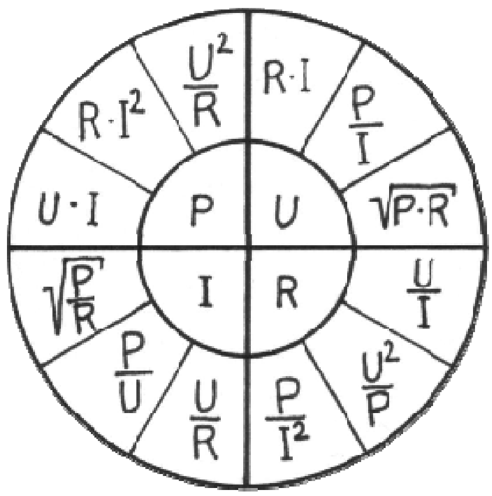
Frequency $f$ in Hz = $\frac{1}{\text{s}}$ in air of 20 °C: $Z = 413 \frac{\text{N} \cdot \text{s}}{\text{m}^3}$

Area through a unit area normal to the direction $A$ in $\text{m}^2$

Displacement of air particles (excursion amplitude) $\xi$ in m

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

To the comparison: U means here V




Particle acceleration $a$ 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 (acoustic 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).