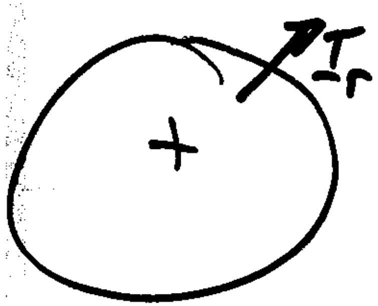
Acoustic Intensity

Sound Power / Unit Area

For complex harmonic signals

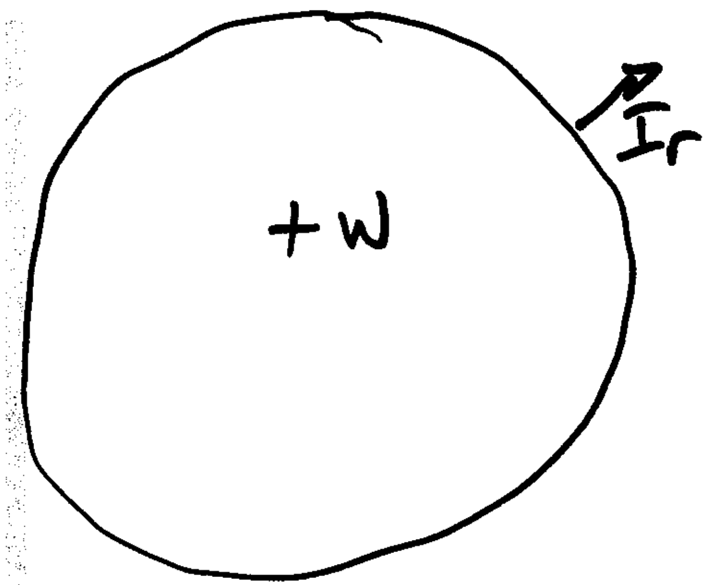
$$\underline{\bar{I}} = \frac{1}{2}\mathrm{Re}\{\tilde{p}\,\tilde{\underline{u}}^*\} \qquad I_x = \frac{1}{2}\mathrm{Re}\{\tilde{p}\,\tilde{u}_x^*\}$$

time-averaged energy flux

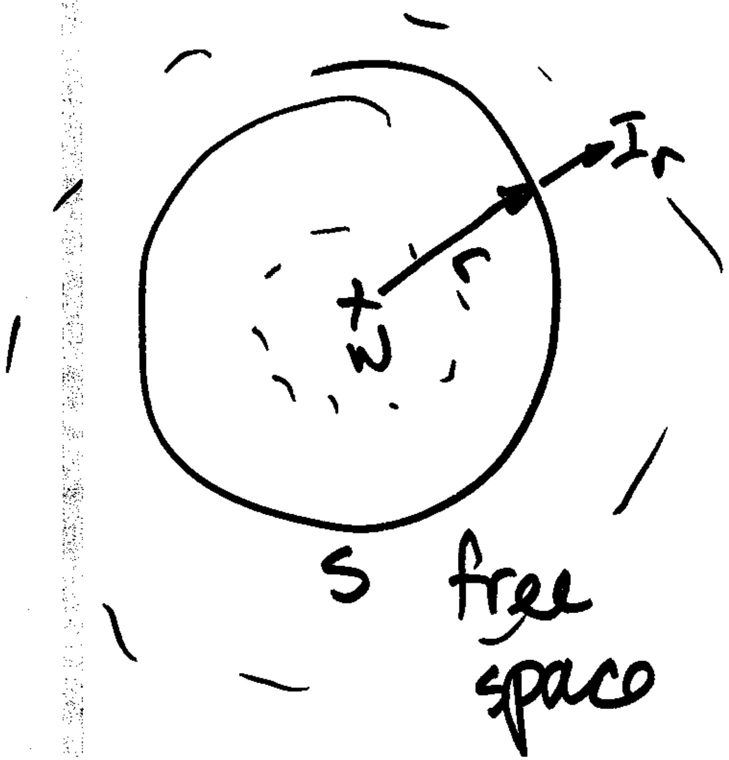


$$I_r = \frac{|\hat{p}_+|^2}{2\rho_0 c} \qquad I_r \propto \frac{1}{r^2}$$

Intensity $\quad \dfrac{\text{Sound Power}}{\text{Unit Area}}$



Sound Power - integrating the normal intensity over a surface enclosing the source.



spherically symmetric

$$W = \int_S I_r \, dS$$

$$= I_r \underbrace{\int_S dS}_{4\pi r^2}$$

W = independent of the measurement position

$$W = \underbrace{4\pi r^2 (I_r)} = \underbrace{4\pi r^2 \frac{p_{rms}^2}{\rho_0 c}}_{\text{freefield}}$$

$$I_r = \frac{W}{4\pi r^2}$$] Inverse Square Law

3.6. Decibels

- sound pressures cover an enormous range in magnitude

Very Loud Sound 20 Pa [120 dB]

Very Quiet 30 dB → 6×10^{-4} Pa

- humans respond on a logarithmic scale

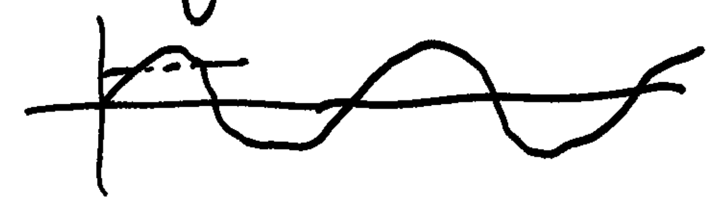
Level - always refers to a decibel

Sound Pressure Level

$$L_p = 10 \log_{10} \frac{p_{rms}^2}{p_{ref}^2}$$

time-averaged mean square pressure

$$p_{rms}^2 = \frac{|p|^2}{2}$$



$$= 20 \log \frac{p_{rms}}{p_{ref}}$$

e.g.

$L_p = 87$ dB re p_{ref}

$$p_{ref}\ (\text{air}) = 20\,\mu Pa \quad \text{root mean square}$$
$$= 2 \times 10^{-5}\ Pa$$

minimum sound pressure healthy young adult can hear at 1 kHz.

Sound ~~B~~ Intensity Level

$$L_I = 10 \log \frac{I}{I_{ref}} \quad dB \quad re\ I_{ref}$$

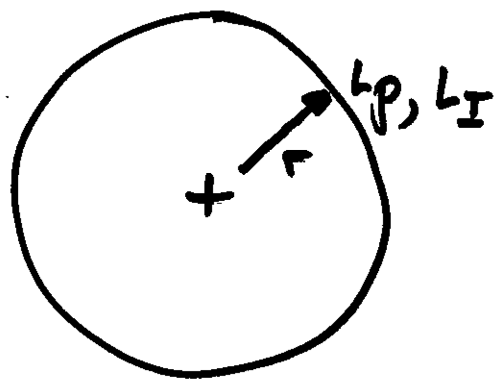
$$I_{ref} = 1 \times 10^{-12}\ \frac{\text{Watts}}{m^2}$$

Freely prop plane wave $\left[I = \frac{p_{rms}^2}{\rho_0 c} = \frac{p_{ref}^2}{\rho_0 c} \right]$

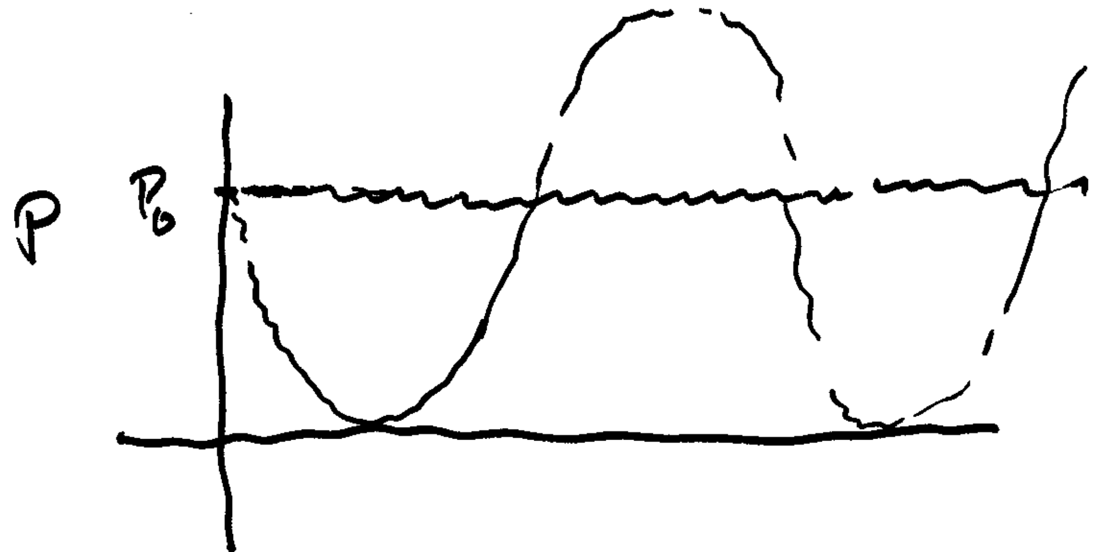
What the choice of I_{ref} means

in a free field

L_p & L_I are numerically (approximately) the same



Always give the reference value when giving a result in dB's



1×10^5 Pa

$$L_p \simeq 10 \log \frac{1 \times 10^{10}}{4 \times 10^{-10}} \simeq 194 \text{ dB re } 20\,\mu\text{Pa}$$

$$0 \leq L_p \leq 194$$

above 120 dB non-linear
effects become
significant

$$\underbrace{70\,dB + 70\,dB}_{73\,dB} \neq \underline{140}\ dB$$

Adding Decibels → adding the corresponding mean square pressures (quadratic quantities)

- assumption that the sounds being added are statistically uncorrelated

$$L_p = 10 \log \frac{p_{rms}^2}{p_{ref}^2}$$

$$(p_{rms}^2)_1 = (10^{L_{p1}/10})\, p_{ref}^2$$

$$(p_{rms}^2)_2 = (10^{L_{p2}/10})\, p_{ref}^2$$

$$\vdots$$

$$(p^2_{rms})_N = \left(10^{L_{pN}/10}\right) p^2_{ref}$$

$$(p^2_{rms})_{total} = (p^2_{rms})_1 + (p^2_{rms})_2 \cdots \cdots + (p^2_{rms})_N$$

$$L_{p\,total} = 10 \log_{10} \frac{(p^2_{rms})_{total}}{p^2_{ref}}$$

$2 \times |p| \rightarrow 4 p^2_{rms} \rightarrow$ increase of $\underline{6\,dB}$

pressure doubling

$L_{p_1} \approx 70$ dB

$L_{p_2} \approx 55$ dB

$$\frac{}{70 \text{ dB}}$$

73
72

$$\frac{}{75}$$

Section 3

Development of The Wave Equation
- assumptions

eqns of state
eqn of continuity
eqn of motion

2nd order PDE

• Linearized momentum equation

pressure field → particle velocity

one-dimensional solutions

- plane
- cylindrical
- spherical

$|p| \neq f(x)$

$|p| \propto \frac{1}{r^{1/2}}$

$|p| \propto \frac{1}{r}$

Specific Acoustic Impedance

$$\tilde{z} = \frac{\tilde{p}}{\tilde{u}}$$

Intensity - time-averaged product of p & $\bar{u}$ - vector quantity

$$\bar{I} = \frac{1}{2} \mathrm{Re}\{\tilde{p}\,\tilde{u}^*\}$$

<ins>Decibels</ins> - always give the reference value.

Level → means dB's