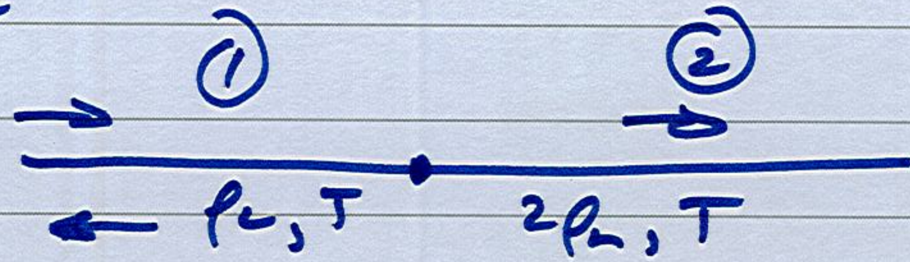
ME 513 Session 20 10/9/15

2.8.2



$$y_1 = \underline{A e^{j(\omega t - k_1 x)}} + B e^{j(\omega t + k_1 x)}$$

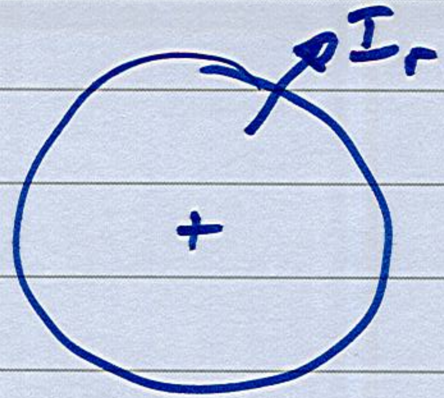
$$y_2 = C e^{j(\omega t - k_2 x)}$$

Acoustic Intensity

$$\bar{I} = \text{sound power / unit area}$$

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

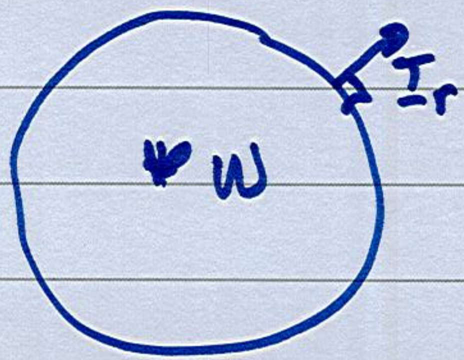
$$= \frac{p_{rms}^2}{\rho_0 c} \quad \text{freely propagating plane wave}$$



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

$$I_r \propto \frac{1}{r^2}$$

no intensity nearfield



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

spher sym $$W = I_r (4\pi r^2)$$

$$I_r = \frac{W}{4\pi r^2}$$

3.6 Decibels

- sound pressure cover an enormous range

Very loud sound 20 Pa [120 dB]

Very quiet 30 dB $\Rightarrow 6\times10^{-4}$ Pa

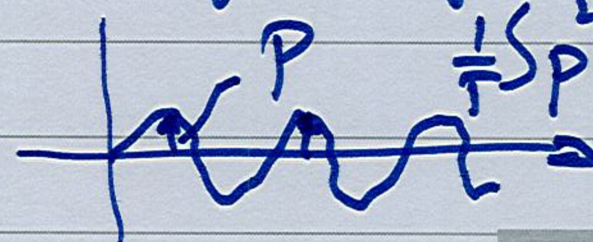
humans respond on a logarithmic scale.

Level - always refers to decibels

Sound Pressure Level

$L_p = 10 \log \frac{p_{rms}^2}{p_{ref}^2}$ ~ mean square pressure

$\frac{1}{T}\int p^2(t)\,dt$



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

$p_{rms} = 0.7P$

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

for sinusoidal signals

$20 \mu Pa$

$= 2 \times 10^{-5}$ Pa

minimum SPL audible by healthy young adult 1 kHz

$L_p = 87$ dB re $20 \mu Pa$

Sound Intensity Level

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

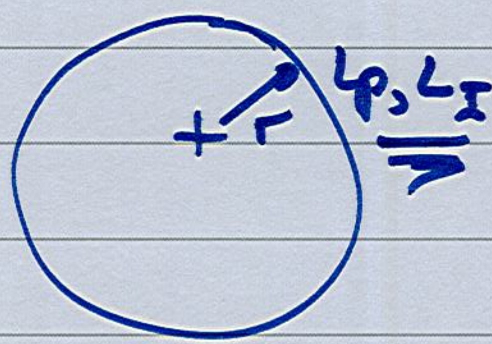
$$I_{ref} = 1 \times 10^{-12} \ W/m^2$$

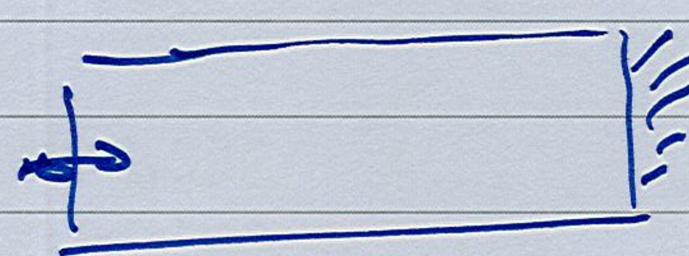
for a freely propagating plane wave

$$I = \frac{P_{rms}^2}{\rho_0 c} = \frac{P_{ref}^2}{\rho_0 c}$$

with This choice
in a free field

L_p & L_I are numerically the same

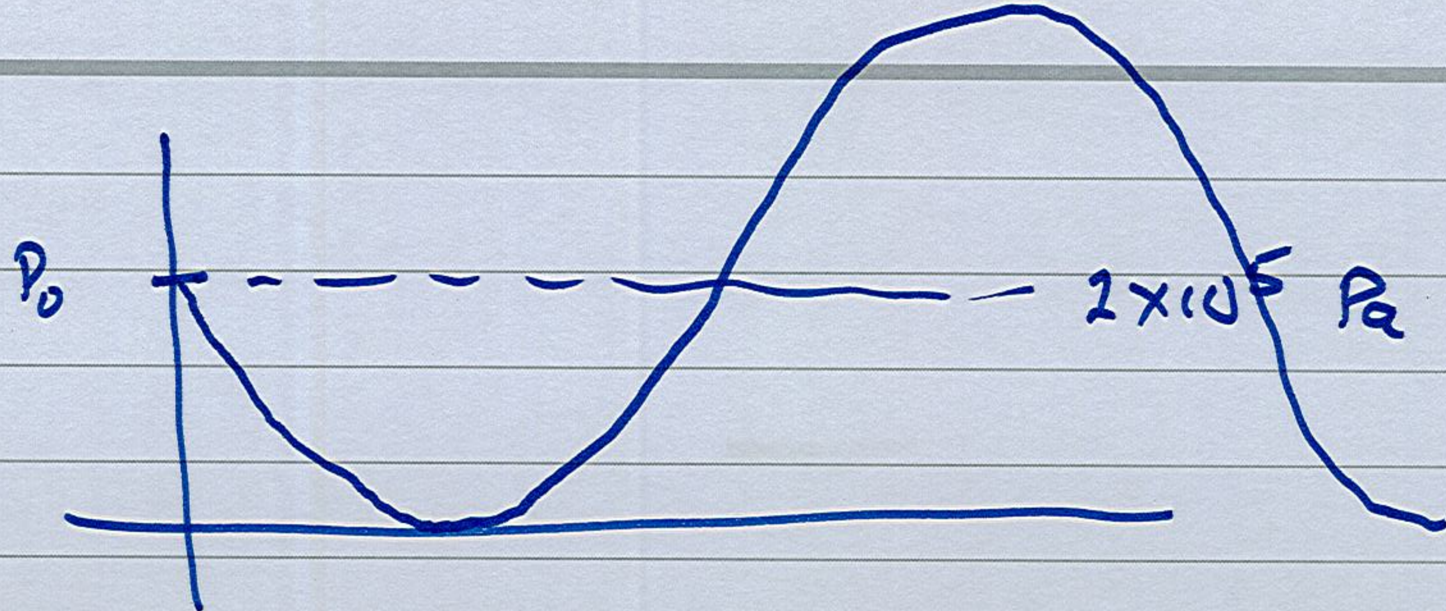




Sound Power Level

$$L_W = 10 \log \frac{W}{W_{ref}} \quad dB \text{ re } W_{ref}$$

$$W = 1 \times 10^{-12} \text{ Watts}$$



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

$0 \leq L_p \leq 194$

above 120 dB
non-linear effects
become significant

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

Adding decibels → add the corresponding mean square pressures (quadratic quantities)

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

$$L_{p_1} + L_{p_2} + \dots \dots = L_{p_{total}}$$

→ assumes signals are statistically uncorrelated

$$(p_{rms}^2)_1 = p_{ref}^2\, 10^{L_{p_1}/10}$$

$$(p_{rms}^2)_2 = p_{ref}^2\, 10^{L_{p_2}/10}$$

$$\vdots$$

$$\vdots$$

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

$$(p^2_{rms})_{total} = (p^2_{rms_1}) + (p^2_{rms_2}) + \cdots$$

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

$$2 \times |p| \Rightarrow 4\, p^2_{rms}$$

$$\underline{\underline{6\ \text{dB}}}\ \Big]\ \underline{\underline{\text{pressure doubling}}}$$

$L_{p_1} \sim 70$ dB

$L_{p_2} \sim 55$ dB

70

$$\begin{array}{r} 73 \\ 72 \\ \hline 75 \end{array}$$

Section 3

Development of Wave Equation

- assumptions

    eqns of state
    " " continuity
    " " motion

  ] 2nd order PDE

• Linearized momentum equation

pressure → particle velocity

One-Dimensional Solutions

- plane $\quad |p| \neq f(x)$
- cylindrical $\quad |p| \propto \frac{1}{r^{1/2}}$
- spherical $\quad |p| \propto \frac{1}{r}$

Specific Acoustic Impedance

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

Intensity – time-averaged product of $\tilde{p}$ & $\overline{u}$

$\frac{1}{2} \mathrm{Re}\{\tilde{p}\,\tilde{\vec{u}}^{*}\}$

vector

Intensity is a vector

Decibels – always give a reference

Levels $\rightarrow$ decibels