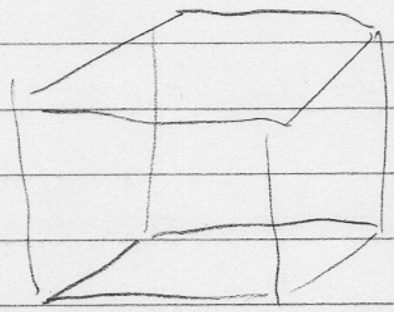
Sound



ρ = density

$\rho = \frac{\text{mass}}{\text{Volume}} = 1.2 \frac{kg}{m^3}$ for air

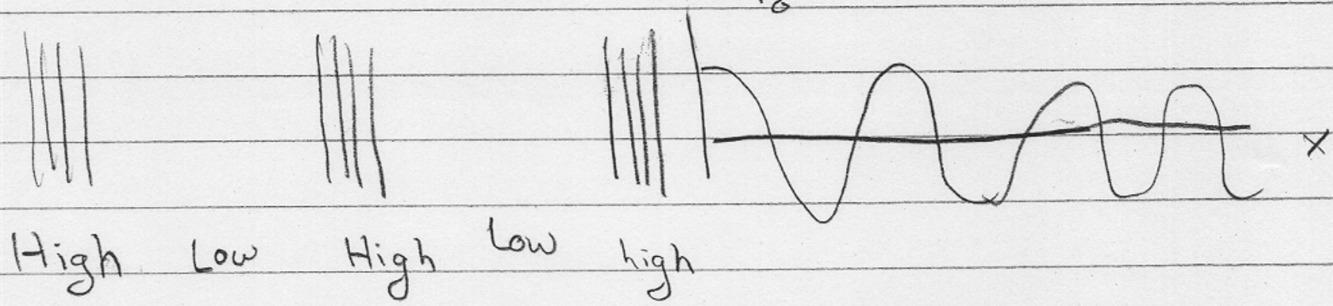
$P = \frac{F}{A} = \frac{\text{Force}}{\text{Area}}$

Units: $\frac{N}{m^2} = 1$ Pascal

10^5 Pascals $= 1$ bar ≈ 1 atm ← pressure in this room

Sound Wave

$\Delta P / P_0 \simeq 1 \times 10^{-5}$ ~ streat noise



The pressure deviation obeys the wave equation

$$\frac{\partial^2 \Delta P}{\partial x^2} = \frac{1}{V_s^2} \frac{\partial^2 (\Delta P)}{\partial t^2}$$

$V_s = 340 \text{ m/s}$ in air at room temperature

The solution for sinusoidal waves

$$\Delta P = \Delta P_m \cos(kx - \omega t)$$

maximum pressure displacement

<u>Energy and intensity</u>

for sinusoidal waves

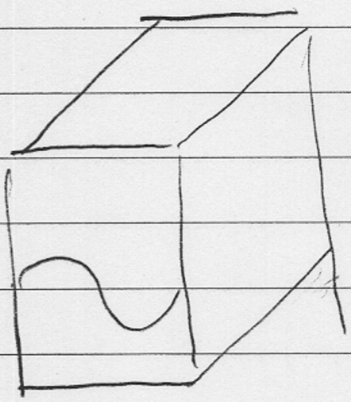
$$\bar{u}_E = \frac{\text{time averaged energy}}{\text{Volume}} \propto \Delta P_m^2$$

$$\bar{u}_E = \frac{\Delta P_m^2}{2 V_s^2 \rho}$$ ← quoted w/out proof

Intensity

$$I = \frac{\Delta E}{A \Delta t} = \frac{\text{energy which cross}}{\text{per area per time}}$$

= " How Lowd it is "



$$\frac{\Delta E}{\Delta t} = u_E \frac{A \lambda}{T}$$

$$I = \frac{\Delta E}{A \Delta t} = u_E \lambda f = \bar{u}_E \cdot v_s = \frac{\Delta P_m^2}{2 v_s \rho}$$

The decibel scale

$$\beta = 10 \log_{10}\left(\frac{I}{I_0}\right) \qquad I_0 = 10^{-12} \frac{W}{m^2}$$

the sound level in dB

or $I = I_0 \times 10^{\beta/10}$

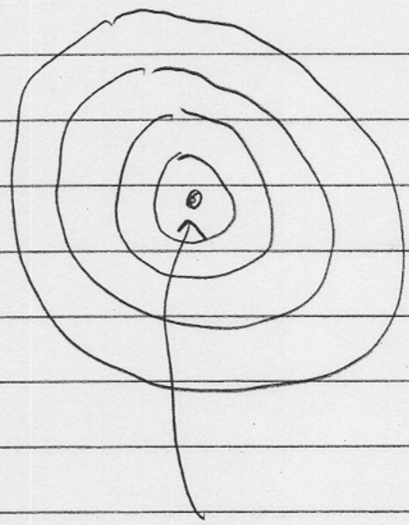
Samples

120 dβ ~ thresh hold of pain

1 dβ ~ whisper

75 dβ ~ streat noise

B) Spherical Waves (Eg. a loud speaker, or Point Source)



power not pressure

$$I = \frac{\Delta E/\Delta t}{A} = \frac{P_o}{4\pi r^2}$$

So expect

$$I \propto \frac{1}{r^2} \quad \text{and} \quad \Delta P_m \propto \sqrt{I} \propto \frac{1}{r}$$

Broad casts @ constant Power P_o

Beats

- First wave

$$\Delta P_1 = A \sin \omega_1 t$$

- Second Wave

$$\Delta P_2 = A \sin \omega_2 t$$

ω_1 + ω_2 just a little different
- See handout

Then

$$\Delta P_{TOT} = \Delta P_1 + \Delta P_2$$

Professor describes what you hear

$$\Delta P_{TOT} = A \sin 2\pi f_1 t + A \sin 2\pi f_2 t$$

There is an average freqwency

modulating frequency

$\bar{f} = \frac{f_1 + f_2}{2}$ and a difference $\Delta f = f_1 - f_2$

So: $f_1 = \bar{f} + \frac{\Delta f}{2}$ and $f_2 = \bar{f} - \frac{\Delta f}{2}$

So

$$\Delta P_{TOT} = A \sin 2\pi\left(\bar{f} + \frac{\Delta f}{2}\right)t \quad + \quad A \sin 2\pi\left(\bar{f} - \frac{\Delta f}{2}\right)t$$

Now

$$\sin(A \pm B) = \sin A \cos B \pm \underbrace{\cos A \sin B}$$

So this term cancels between $f + \frac{\Delta f}{2}$ and $f - \frac{\Delta f}{2}$

So

$$\Delta P_{TOT} = 2A \sin\left(2\pi \bar{f} t\right) \cos\left(2\pi \frac{\Delta f}{2} t\right)$$

$$\Delta P_{TOT} = 2A \sin\left[2\pi\left(\frac{f_2 + f_1}{2}\right)t\right] \cos\left[\frac{2\pi(f_2 - f_1)t}{2}\right]$$

rapid oscillations

slow oscillations at the beat frequency $\frac{\Delta f}{2}$

see handout for graph