SOUND

a) There is NO sound in vacuum; you need matter to propagate a sound wave.
b) SOUND: Any mechanical wave whose frequency lies between 20*Hz* and 20,000*Hz*, that is, $20Hz \le f \le 20kHz$ (It is called sound because you can hear it!).
c) We will work with sound in Gases only-then sound is a purely Longitudinal wave.
d) Sound is a longitudinal displacement wave or a longitudinal pressure wave.
e) Periodic Sound wave properties

DISPLACEMENT	PRESSURE
*Sin*e wave, $\varnothing = 0$ $S = S_m Sin(\kappa x - \omega t)$ amplitude $\underset{\rightarrow}{S_m} \parallel \hat{x}$ $\omega = vk$	To write corresponding pressure wave we have to realize that the variation occurs so rapidly that there is no possibility for exchange of heat (DQ) to ensure equilibrium with surroundings, so DQ=0, sound is an adiabatic process: Pressure and Volume satisfy: $P_0 V_0^{\gamma}$ = constant. P_0 = ambient pressure $\gamma = \frac{C_p}{C_v}$, C_p = sp ht at const P C_v = sp ht at const V $\gamma_{monoatomic} = \frac{5}{3}$ $\gamma_{diatomic} = \frac{7}{5}$ $\rightarrow \varnothing = \frac{-\pi}{2}$ $P = P_0 - \gamma P_0 S_m \kappa \, Cos(\kappa x - \omega t)$
Displacement oscillates about zero.	Pressure oscillates about P_0 Amp of pressure wave $P_m = \gamma P_0 S_m \kappa$ $\underset{\rightarrow}{P_m} \parallel \hat{x}$ Pressure is $\frac{\pi}{2}$ out of phase with displacement where S is max. $(P-P_0)=0$!

f) Speed of sound in a gas

$$v = \sqrt{\frac{\gamma P_0}{\rho_0}}$$

ρ_0 = ambient density

since $P_0 V_0 = N\,k_B T$ $\left[k_B = 1.383x10^{-23} J/K\right]$

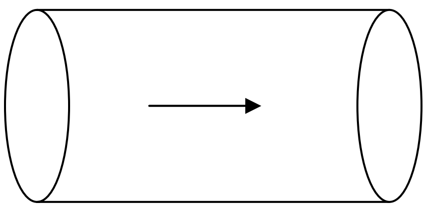
If gas particles have mass *m*, we can write

$$P_0 = \frac{Nm}{V_0}\frac{k_B}{m}T, or\, \frac{P_0}{\rho_0} = \frac{k_B T}{m}$$

$$v = \sqrt{\frac{\gamma k_B T}{m}} = \sqrt{r}\,\frac{v_{rms}}{\sqrt{3}}$$

[*T* in Kelvin Scale]

g) Intensity of sound wave: Imagine that the wave is traveling with velocity *v* through a tube of cross-section *A*.



Since $S = S_m Sin\,(\kappa x - \omega t)$ the particle velocity is $V_p = S_m \omega \cos(\kappa x - \omega t)$ and kinetic energy per unit volume is $K \cdot E = \frac{1}{2}\rho_0 S_m{}^2 \omega^2$.
Volume of wave traveling past every cross-section will be Av in one second.
Energy transport per second through area

$$A = \frac{1}{2} A \rho_0 S_m{}^2 \omega^2 v$$

Intensity I=energy transport per second per m^2

$$= \frac{1}{2}\rho_0 S_m{}^2 \omega^2 v \qquad \left[\rho_0 = \frac{\gamma P_0}{v^2}\right]$$

$$= \frac{1}{2}\gamma P_0 S_m{}^2 \frac{\omega^2}{v}$$

Please compare this with energy transport per second on wire $\langle P \rangle = \frac{1}{2} A^2 \frac{\omega^2}{v} \cdot F$

h) Smallest discernable intensity is $I_0 = 10^{-12} Watt/m^2$

So we define decibels $db = 10\log\frac{I}{I_0}$ [bel comes from Alexander Graham Bell]

That is 90*db* sound has $9 = \log\frac{I}{10^{-12}}$, $I = 10^{-3} Watt/m^2$

i) Amplitude of displacement wave for I_0 $(w = 10^3 rad/s, \gamma = 1.4, P_0 = 10^5 N/m^2)$,

$$10^{-12} = \frac{1}{2} x 1.4 x 10^5 x \frac{S_m{}^2 x 10^6}{340}$$

$$S_m \cong 10^{-10} m$$

Roughly equal to diameter of hydrogen atom. REMARKABLE!!!

That is your ear is sensitive to motion of air molecules where displacement is equal to the diameter of a hydrogen atom. Congratulations!!