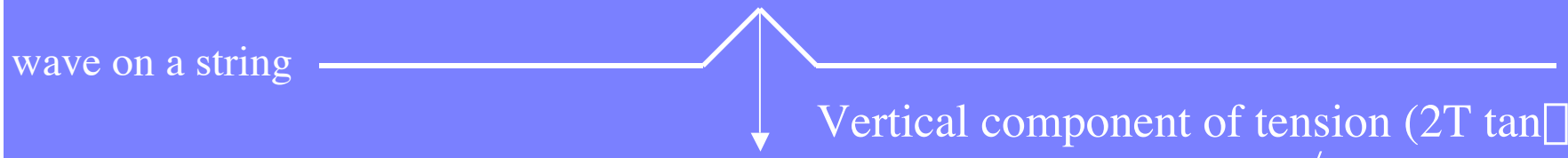
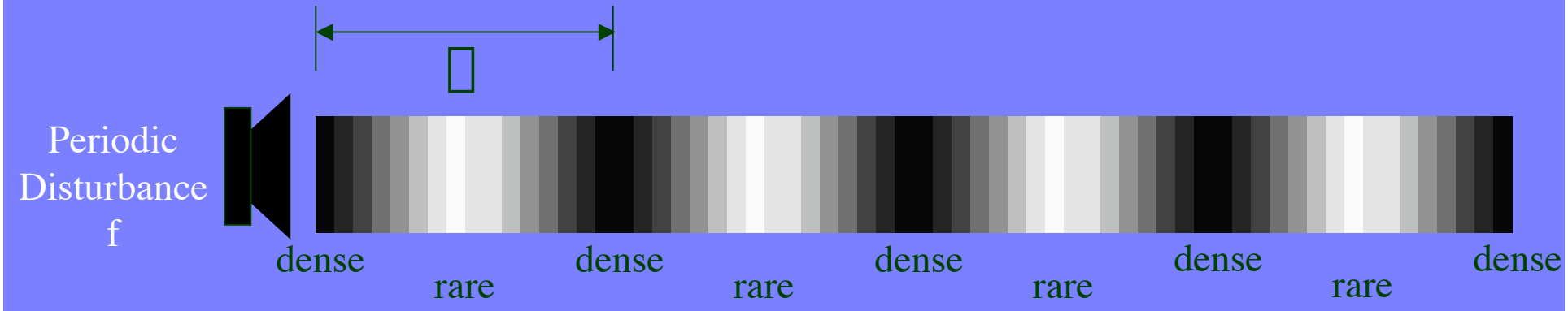
Lecture 19: Properties of Sound

- Sound is a COMPRESSION "wave"
  - wave: propagating disturbance from equilibrium



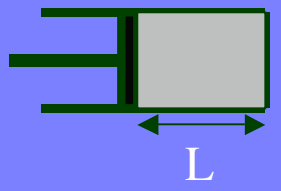
Tuning a violin string: f=(√T/μ)/L



Properties of Sound

– Elastic medium Stress=Y*Strain

$$dP/dV=-Y/V$$

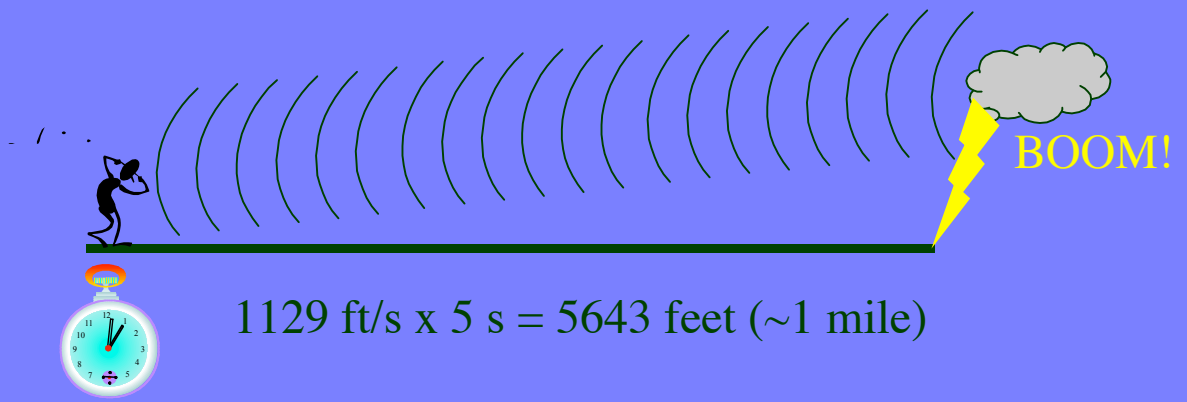


Ideal Gas $Y=nRT/V$

$$c=1.3\sqrt{Y/\rho}=1.3\sqrt{RT/M}$$

Mol. wgt. (kg/mole)

$$=344 \text{ m/s (Air)}$$



Properties of Sound

amplitude frequency phase

$$P = P_0 \cos(\omega t + \phi)$$

$$A = A_0 \cos(\omega t + \phi)$$

$$\omega = 2\pi f$$

$$c = \lambda f$$

$$c = 1.3\sqrt{RT/M}$$

Sound Intensity

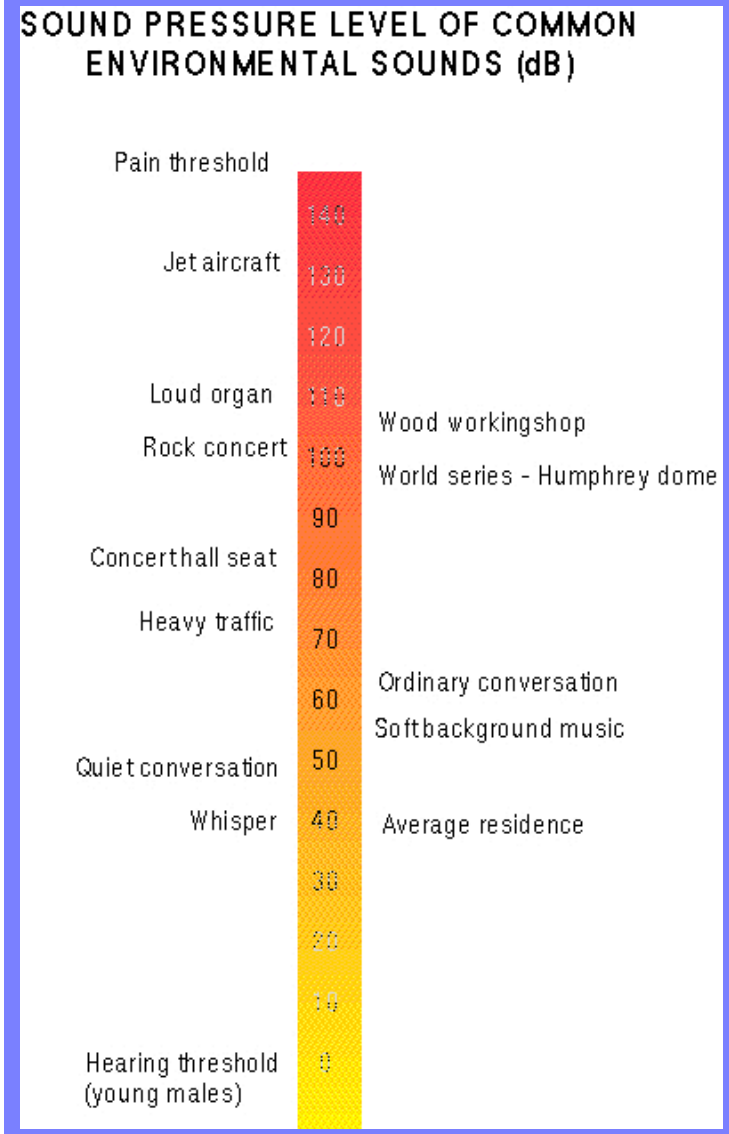
$$I = 1/2\ \rho c A_0^2 \omega^2 = 1/2\ \rho A_0^2 \omega^2 = 1/2\ P_0^2/Z$$

Z=ρY: Acoustic Impedance

dB (decibles) Measures I

$$L = 10 \log_{10} (I/I_0)$$
$$I_0 = 10^{-12}\ w/m^2$$

0 dB	Threshold of Hearing
20 dB	Whisper
30 dB	Average home
60 DB	Talking (1 meter away)
70 dB	Busy Street
85 dB	OSHA limits



Audiogram

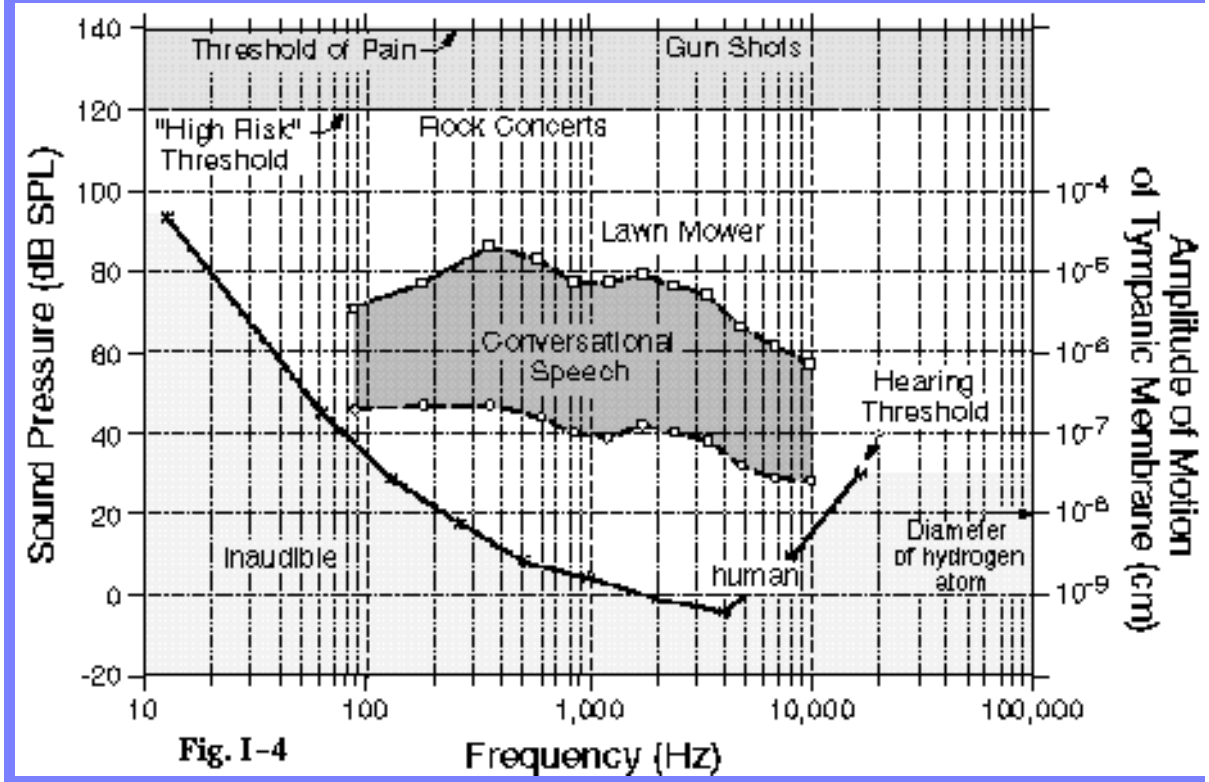
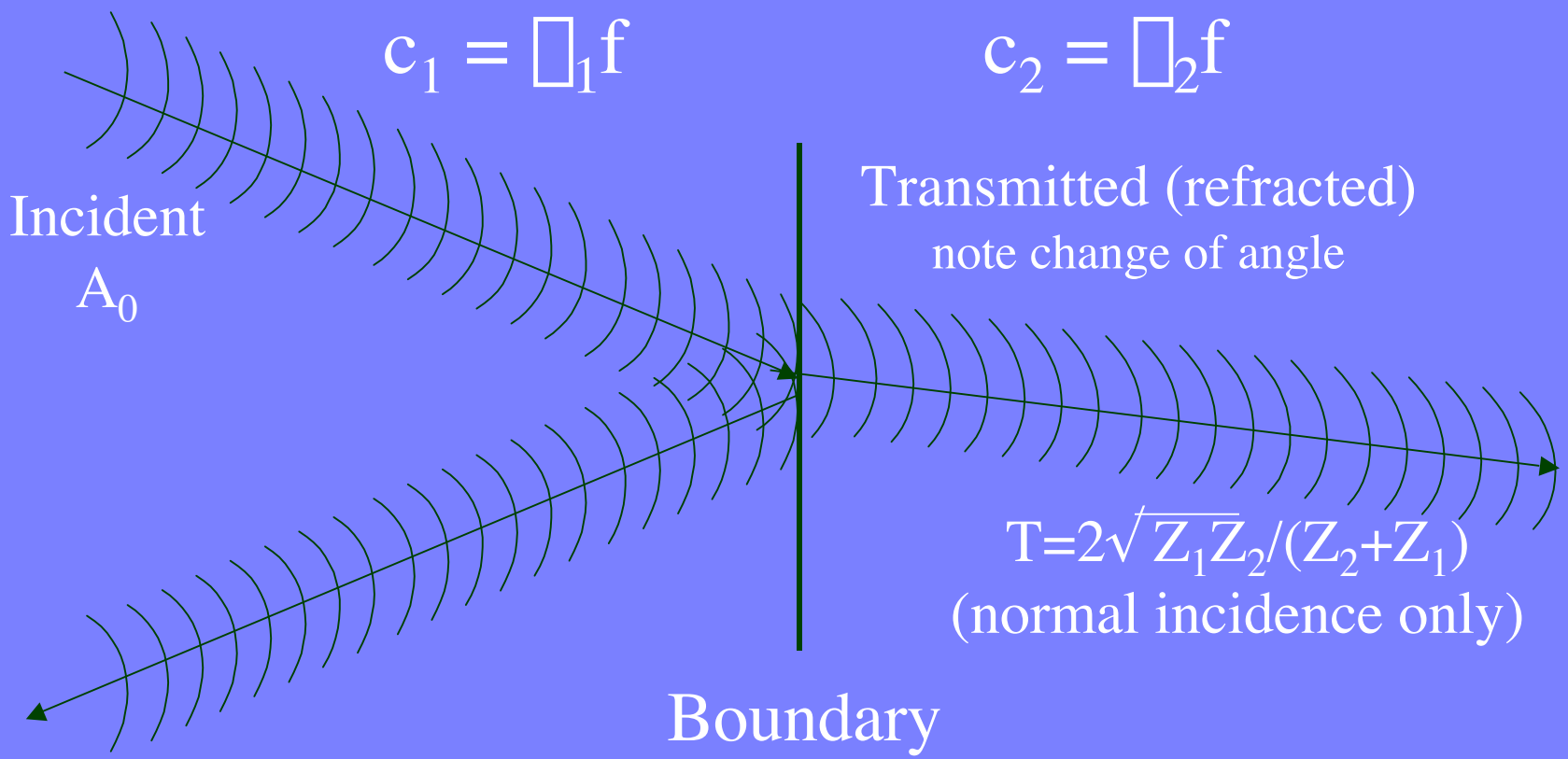


Fig. I-4

Wave Properties:
Reflection, Transmission, Refraction

$c_1 = \lambda_1 f$ $c_2 = \lambda_2 f$



$R^2+T^2 = 1$ (conservation of energy)

Accoustic Impedance

$Z = \rho c$

	c (m/s)	Z 10^6 kg/m^2/s
Air	344	0.0004
Water	1484	1.48
Blood	1550	1.61
Myocardium	1550	1.62 (perpendicular to fibers)
Muscle	1580	1.64
Liver	1570	1.65
Kidney	1560	1.62
Fat	1450	1.38
Skull Bone	3360	5.69 (compressive)

(ρ=1.78 gm/cm^3, Y= 1.8x10^8 N/m^2)

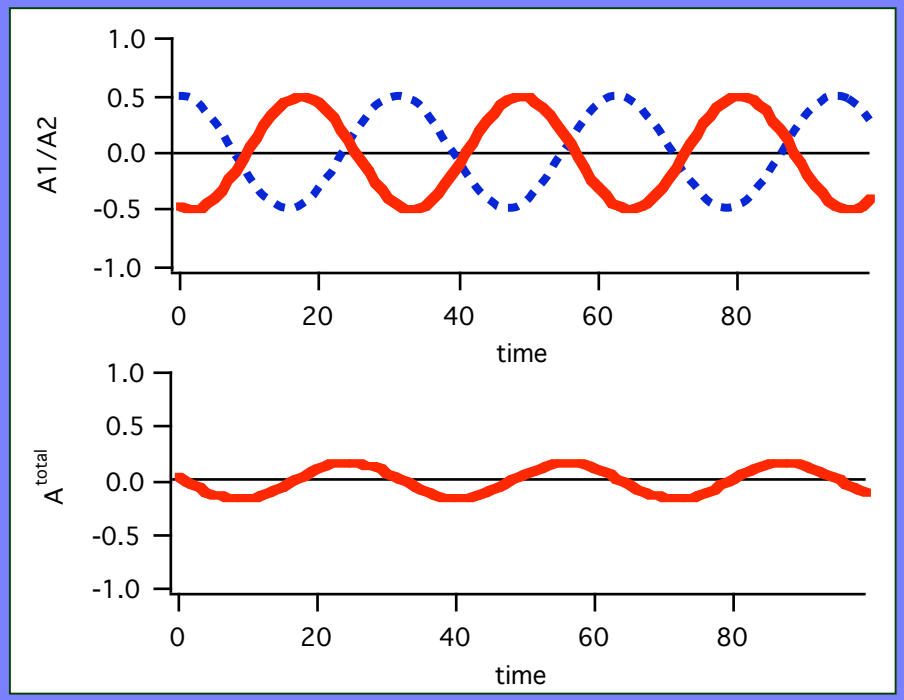
More Wave Properties: Interference and Diffraction

Combining Waves Together

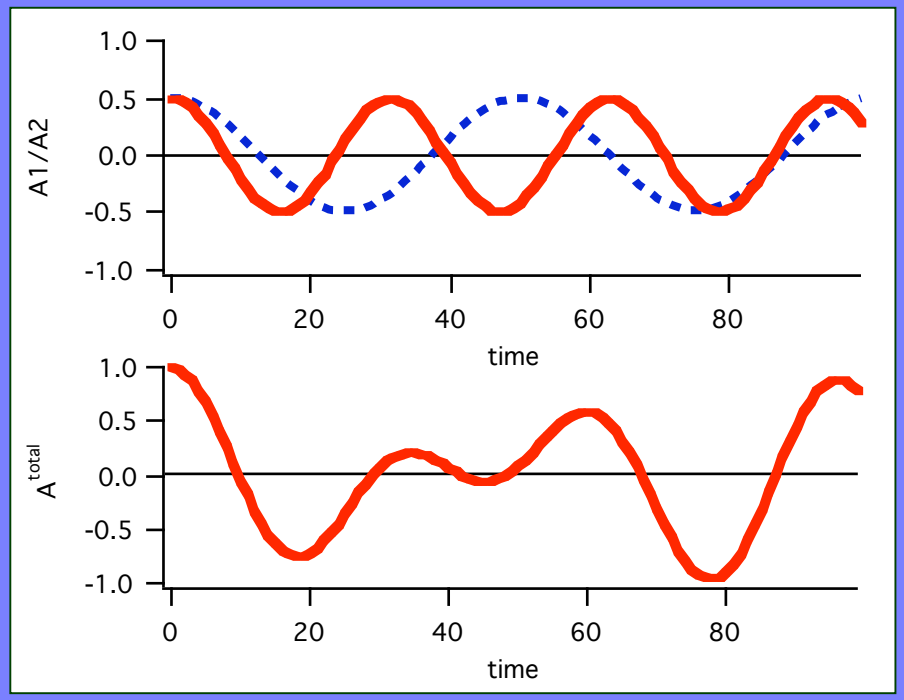
$$A^1 = A^1_0 \cos(\omega_1 t + \phi_1) \qquad A^2 = A^2_0 \cos(\omega_2 t + \phi_2)$$

$$A^{total} = A^1 + A^2$$

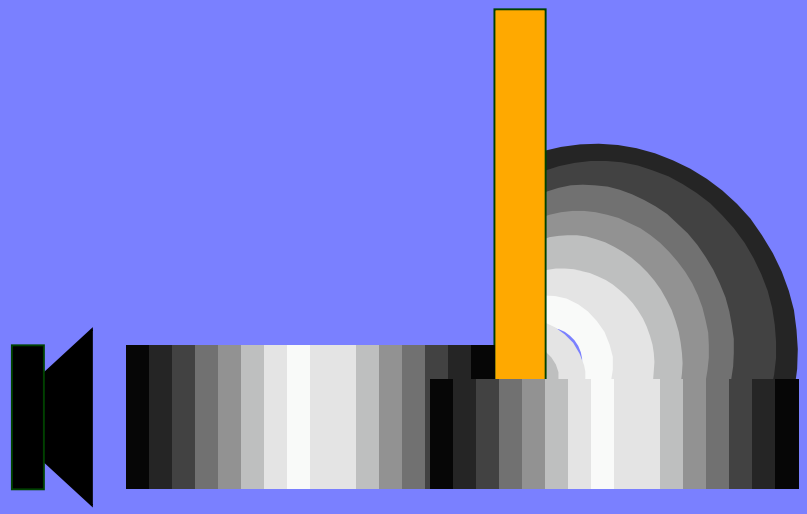
Different Phases



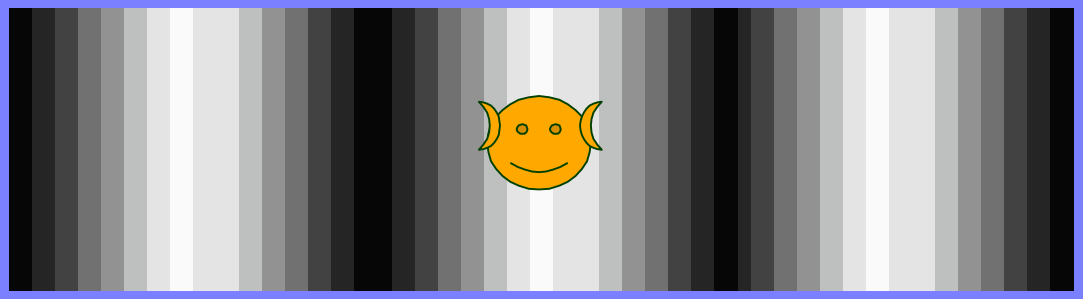
Different Frequencies



Diffraction:
Waves Move Around Corners



If □>> D, Not Much Shadow

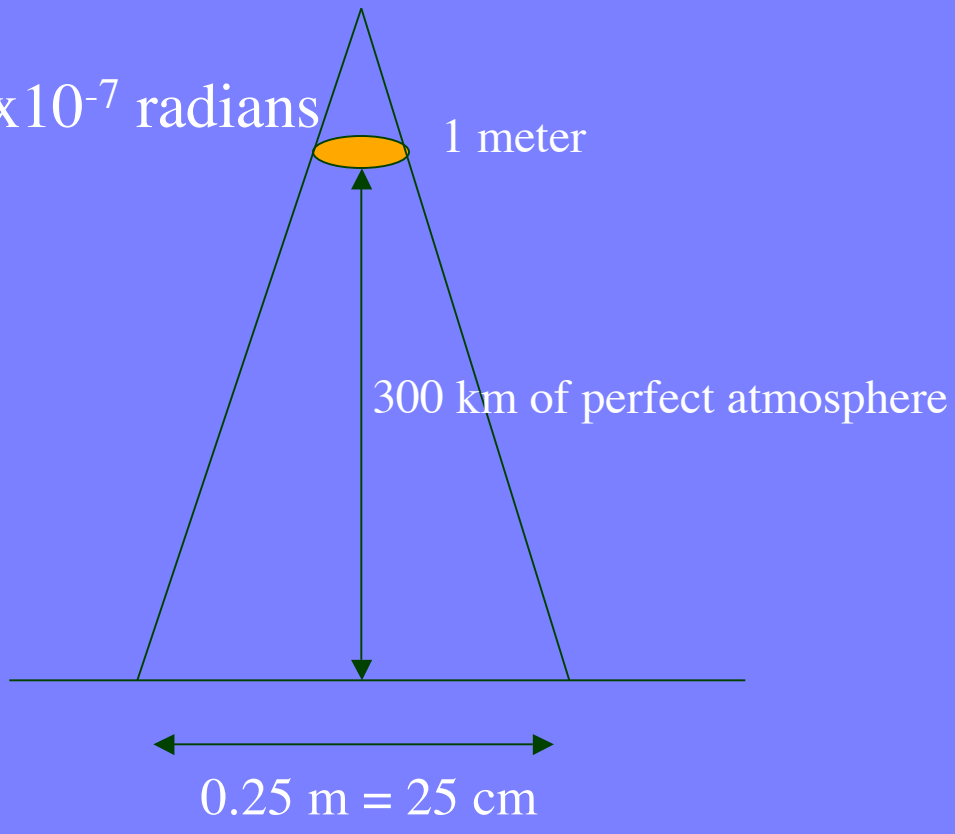


Diffraction

Diffraction limits angle resolution

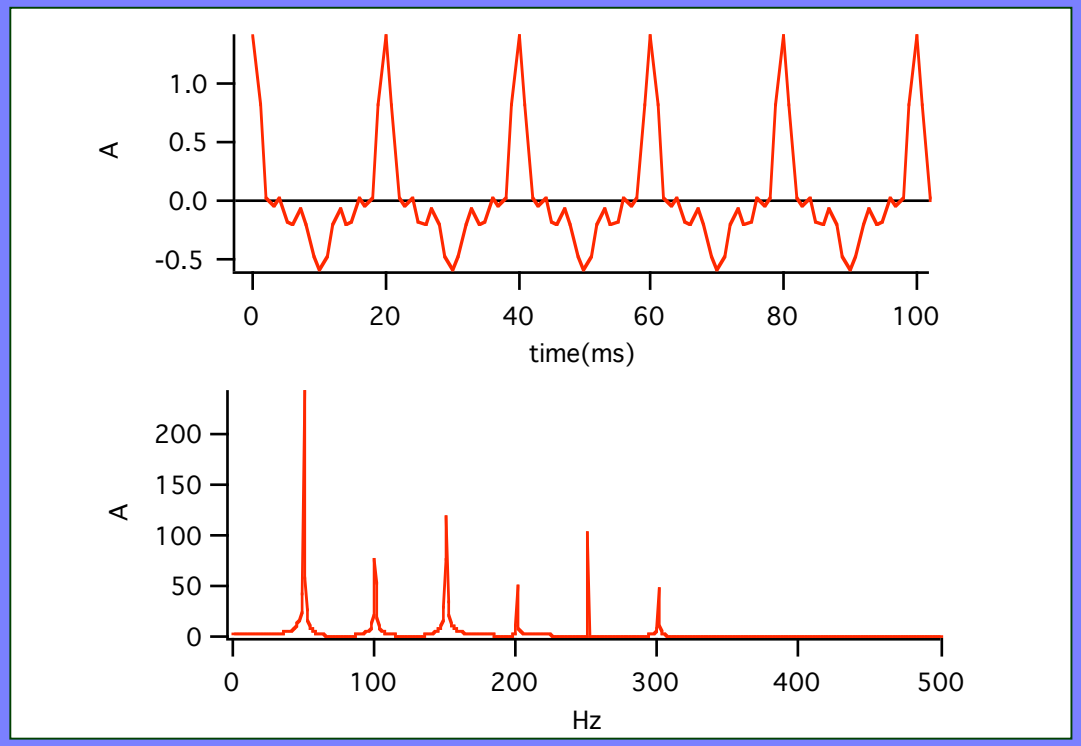
$\theta = 1.22\ d \sin \theta$

$2\theta \approx 2\theta = 1.22\ d) = 8 \times 10^{-7}$ radians

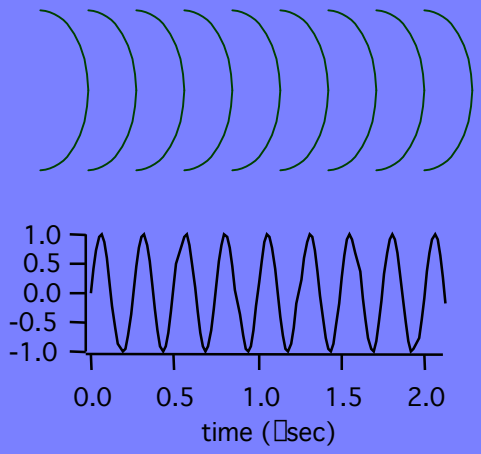


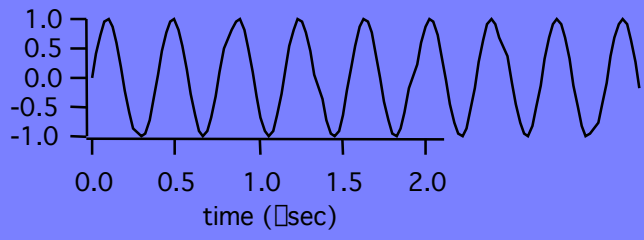
Sound Spectum

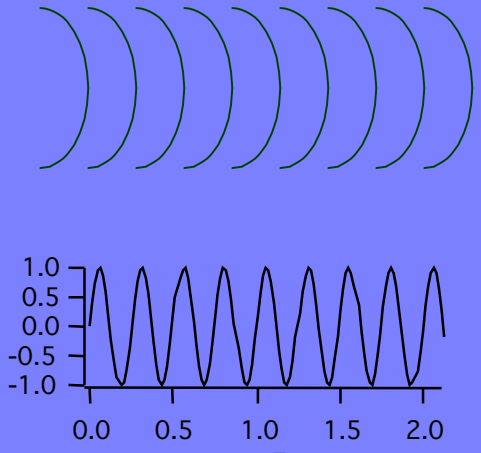
Sound is not (naturally) single frequency

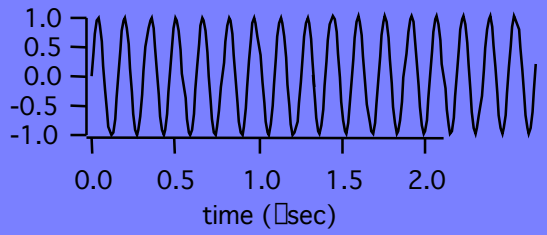


Doppler Shift









$\Delta f = v/c * f$