8-30-13

x and t
↓
MOLECULE VIBRATES

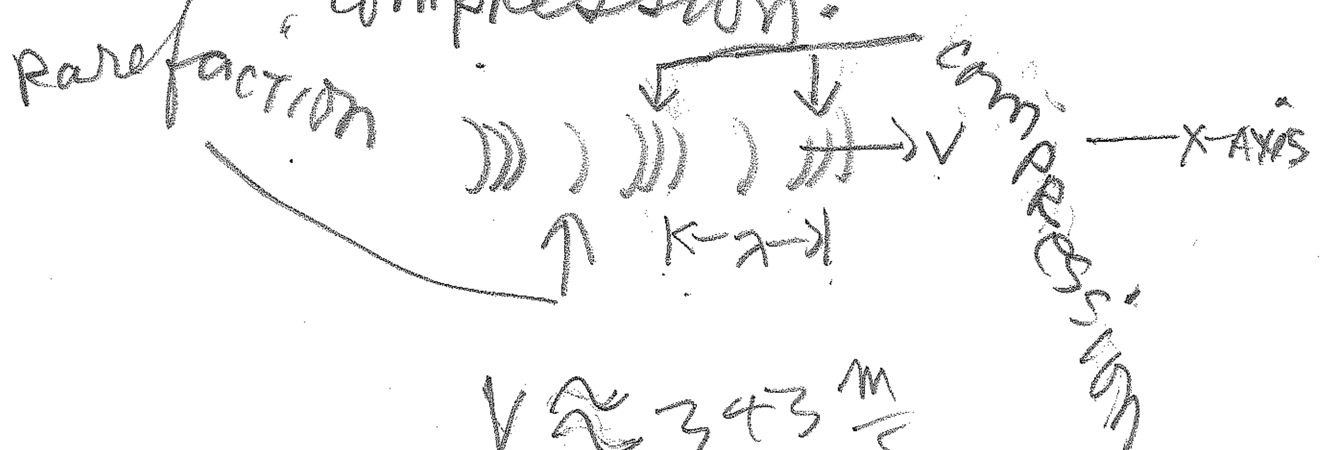
CH 16

wave:

$y(x,t) = A\cos(\omega t - \omega t)$

= instantaneous displacement y (from equilibrium) in medium at x and t.

"state of displacement" moves right; 2 special states: rarefaction and compression:



$v \approx 343 \frac{m}{s}$

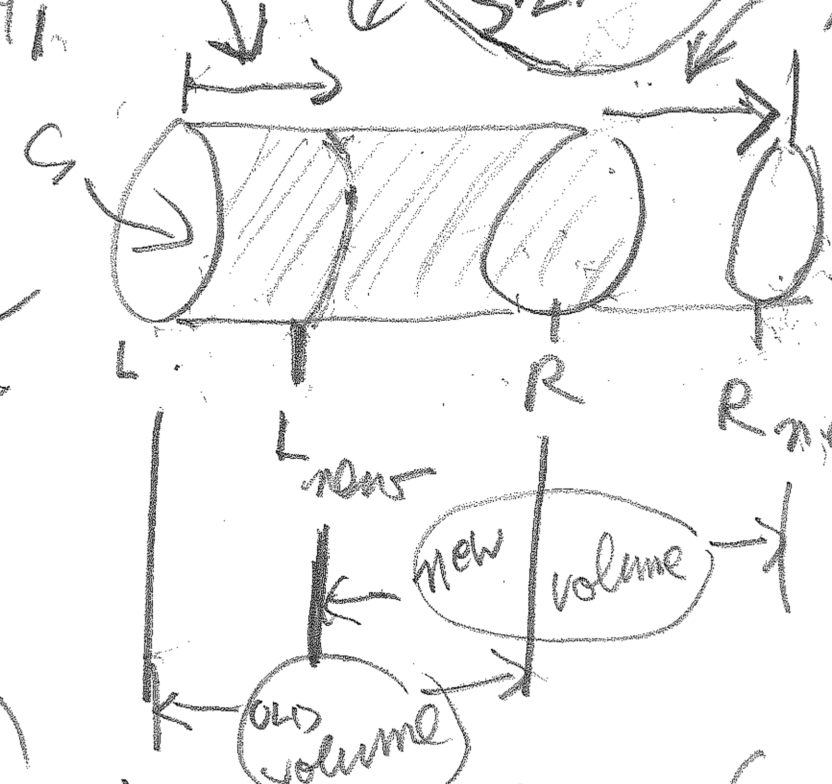
Derive equation for pressure P from Y:

$Y_1 = Y(x, t)$

NO SOUND $S \cdot \Delta X = V_0$ $(t=0)$ ②

$Y_2 = Y(x+\Delta x, t)$

fig 6.2



ΔV is change after t

X $(t=0)$ $X+\Delta X$ $(t=0)$ (let $\Delta x \to 0$)

dV is change after dt

$Y_2 < Y_1$ volume decreases

$Y_2 > Y_1$ " increases

$Y_1 = Y_2$ " same (ONLY SHIFTS)

change in volume at time t (from $t=0$)

$$\Delta V = S \cdot (Y_2 - Y_1) = S \cdot \left[y(x+\Delta x, t) - y(x, t) \right]$$

$$\frac{\Delta V}{V_0} = \frac{S\left[y(x+\Delta x, t) - y(x,t)\right]}{S \cdot \Delta x} \xrightarrow[\Delta x \to 0]{\lim} = \frac{\partial y}{\partial x} = \frac{dV}{V_0}$$

$$\frac{dV}{V} = \frac{\partial y}{\partial x}$$

3D spring constant

sec 11.4:

$$B = \frac{-\Delta p}{\Delta V / V_0}$$ ← change (fluctuation)

NOTE: P4A

$$B = \frac{-p(x,t)}{(dV/V)}$$ ← (fluctuation) in pressure

$$\Rightarrow p = -B\frac{dV}{V}$$

$$= -B\frac{\partial y}{\partial x}$$

$p(x,t)$ = fluctuation about P_0 ← ambient pressure

$$p(x,t) = BkA\sin(kx - \omega t)$$

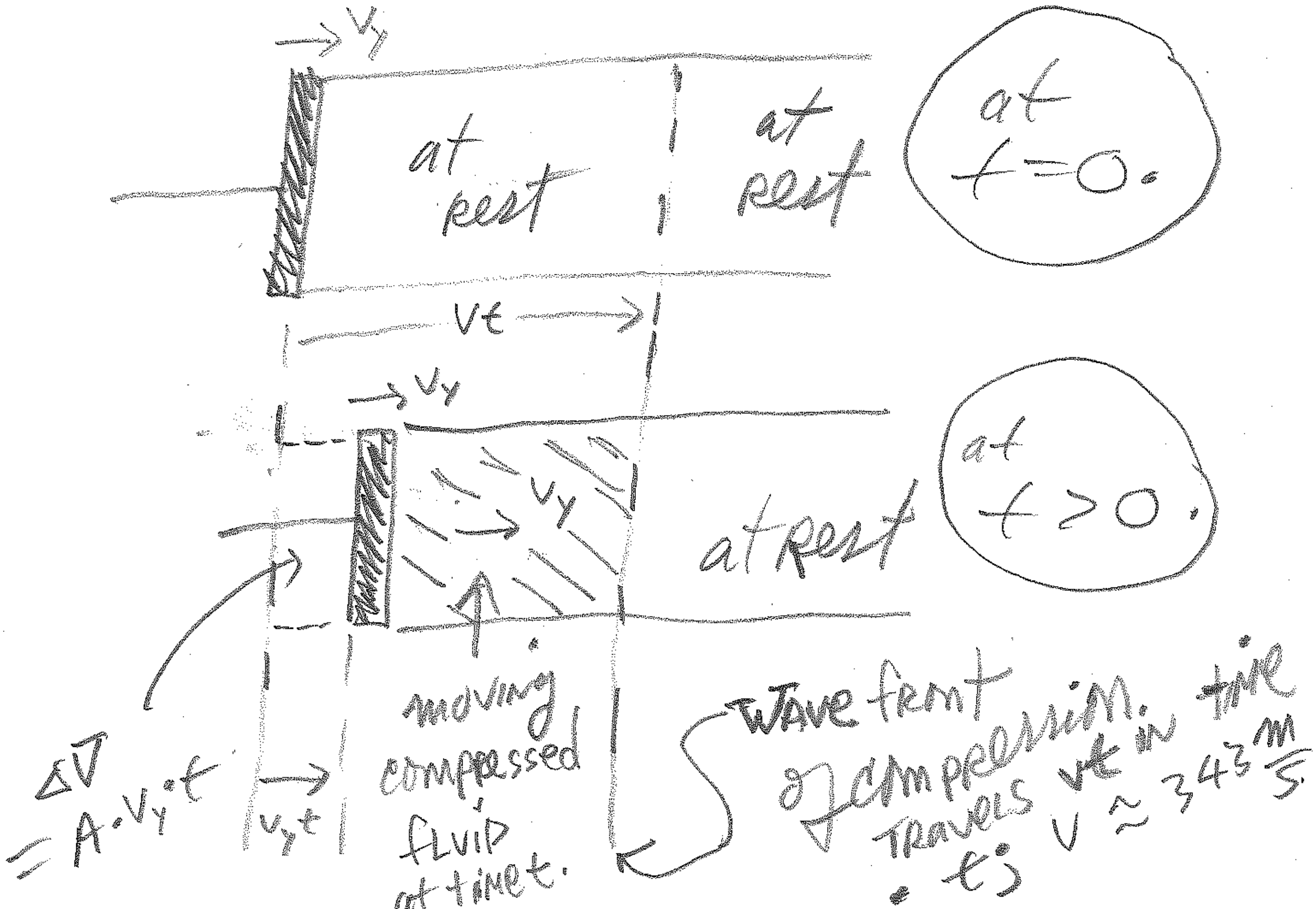
fluctation (small amplitude of molecule oscillation)

HINT: $y \propto \cos(\ )$

$\partial y/\partial t \propto \sin(\ )$

16.2 speed of waves

PROJE $v = \sqrt{\frac{B}{\rho}}$



At $t=0$, press piston RIGHTWARD with speed v_y; continue pressing for time t. Longitudinal momentum of moving section: mass $\cdot v_y = (\rho \cdot A \cdot vt) v_y$

$$B = \frac{-\Delta p}{\Delta V / V_0} = \frac{-\Delta p}{\left(\frac{-A v_y t}{A \cdot vt}\right)} = +\Delta p \cdot \frac{v}{v_y}$$

$$\rightarrow \boxed{\Delta p = B \cdot \frac{v_y}{v}}$$

5)

change in pressure $= \boxed{\Delta p = B\frac{v_y}{v}}$

$F \cdot t$ = change in momentum

$$\Delta p \cdot A \cdot t = (\rho v t \cdot A) v_y$$

$$B\frac{\cancel{v_y}}{v} \cdot \cancel{A t} = (\rho v \cancel{t \cdot A}) \cancel{v_y}$$

$$\frac{B}{\rho} = v^2$$

$$\sqrt{\frac{B}{\rho}} = v$$

speed of sound in gas

$$V = \sqrt{\frac{\gamma R T}{M}}\ ; \quad M = \text{molar mass } \left(\frac{kg}{mole}\right)$$

T = temperature

$$R = 8.3144 \frac{J}{mol \cdot K}$$

Example $T = 293K$
$= 20°C$

$\gamma = 1.4$

$M = 28.8 \times 10^{-3} \frac{kg}{mole}$ (AIR)

$V = 344 \frac{m}{s}$, as expected

7

$$p(x,t)\cdot v_y(x,t) = \underline{I} = \text{Intensity}$$

$$\underline{I} = BkA\sin(kx-\omega t)\cdot\omega A\sin(kx-\omega t)$$

$$\underline{I} = B\omega kA^2\sin^2(kx-\omega t)$$

$$\left(\frac{J}{s\cdot m^2}\right)$$

$$I = \text{intensity}\left(\frac{J}{s\cdot m^2} = \frac{\text{Watts}}{m^2}\right)$$

$$\langle I\rangle = B\omega kA^2\langle\sin^2(kx-\omega t)\rangle$$

$$= \frac{B\omega kA^2}{2}\left(\frac{W}{m^2}\right)$$

Intensity in decibels

$$I = \frac{1}{2} B \omega k A^2$$

$$I = \frac{1}{2} \sqrt{\rho B} \cdot \omega^2 A^2$$

since $\sqrt{\rho B} \cdot \omega^2 = B \cdot \omega \cdot k$

OR

$$\frac{1}{v} = \sqrt{\frac{\rho}{B}} = \frac{k}{\omega} \rightarrow v = \sqrt{\frac{B}{\rho}}$$

$$\Updownarrow$$

$$I = \frac{\omega P_{max}^2}{2Bk} = \frac{v P_{MAX}^2}{2B} \quad \text{since } v^2 = \frac{B}{\rho}$$

$$I = \frac{P_{MAX}^2}{2\rho v} = \frac{P_{MAX}^2}{2\sqrt{\rho B}}$$

Decibels: $\beta = (10\,dB)\log\frac{I}{I_0}$

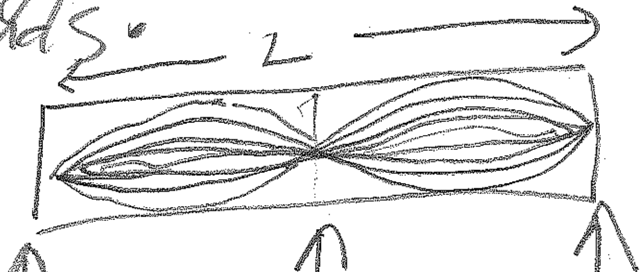
TO CONTROL VAST CHANGES IN I

<u>NOTE</u>: $I_0 = 10^{-12}\frac{W}{m^2}$; <u>RADIO</u>: $I = 10^{-8}\frac{W}{m^2}$; <u>TRAIN</u>: $I = 10^{-3}\frac{W}{m^2}$

Sec 16.4

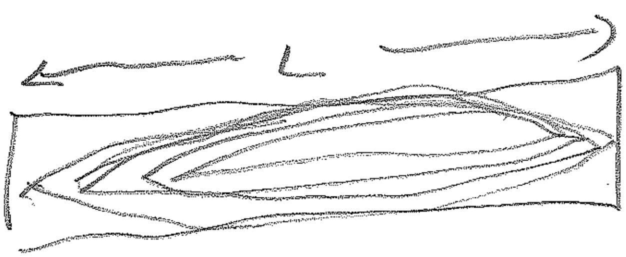
closed and open pipes

fig. 16.13; closed at both ends.

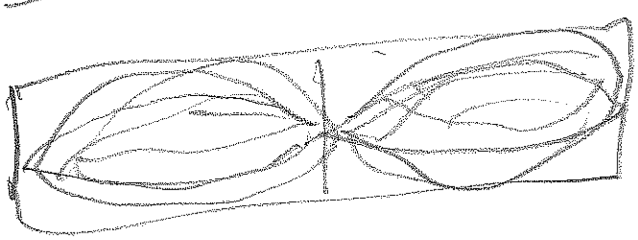


note: $L = \lambda$ (fig. 16.13)

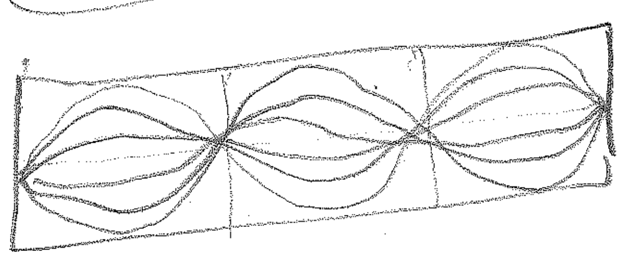
Node Node Node ← displacement nodes



$f_1 = \frac{(1)v}{2L}$



$f_2 = \frac{(2)v}{2L}$



$f_3 = \frac{(3)v}{2L}$

Same as string!

$f_n = \frac{nv}{2L}$

$n = 1, 2, 3, 4 \ldots$

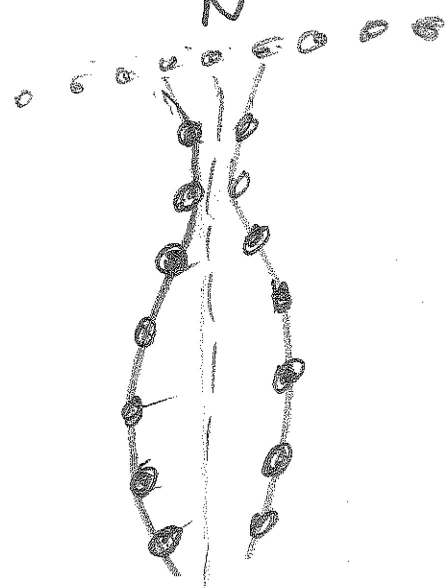
Fig 16.13:

NOTE: a Displacement
Node N corresponds
to a pressure* anti-node
(MAXIMUM AMPLITUDE).

zero + amplitude

* pressure change

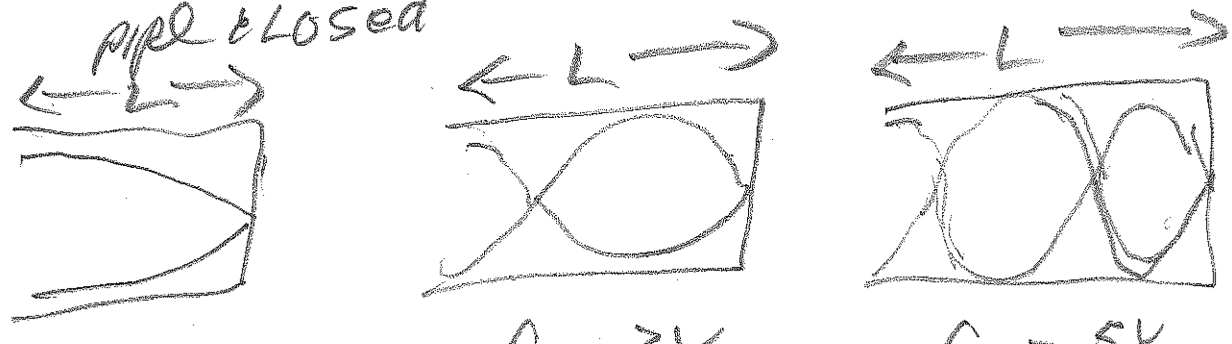
N = displacement
Node (zero always)



A = pressure
anti node
(MAX OR MIN)

Todays Lab 16.18

pipe closed



$f_1 = \frac{v}{4L}$

$f_3 = \frac{3v}{4L} = 3f_1$

$f_5 = \frac{5v}{4L} = 5f_1$

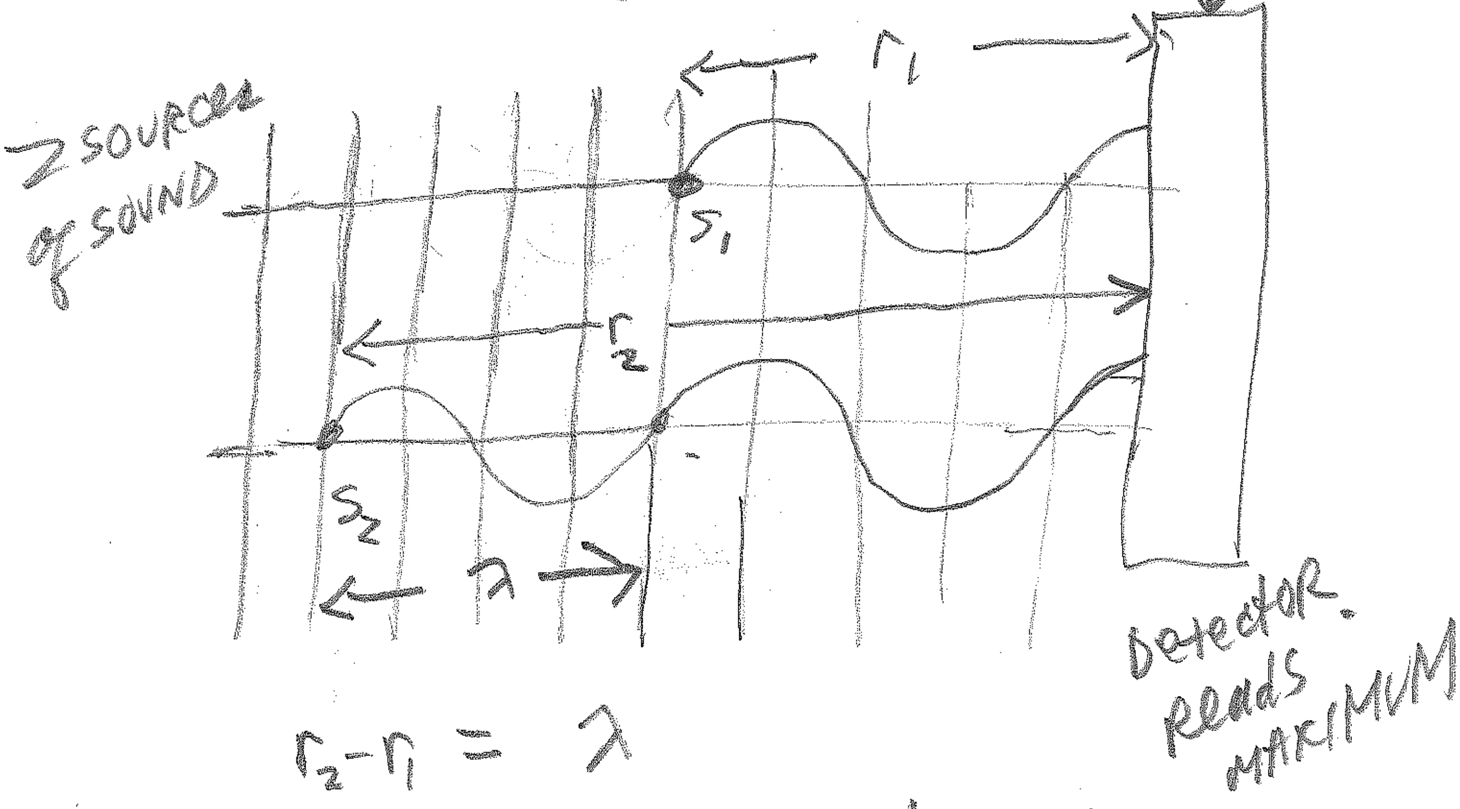
$$f_n = \frac{nv}{4L}, \; n = 1, 3, 5 \ldots$$

Resonance : drive system at natural frequency result in LARGE ENERGY absorption and amplitude.

In Lab we VARY L, f = constant

Interference

constructive interference:



$r_2 - r_1 = \lambda$

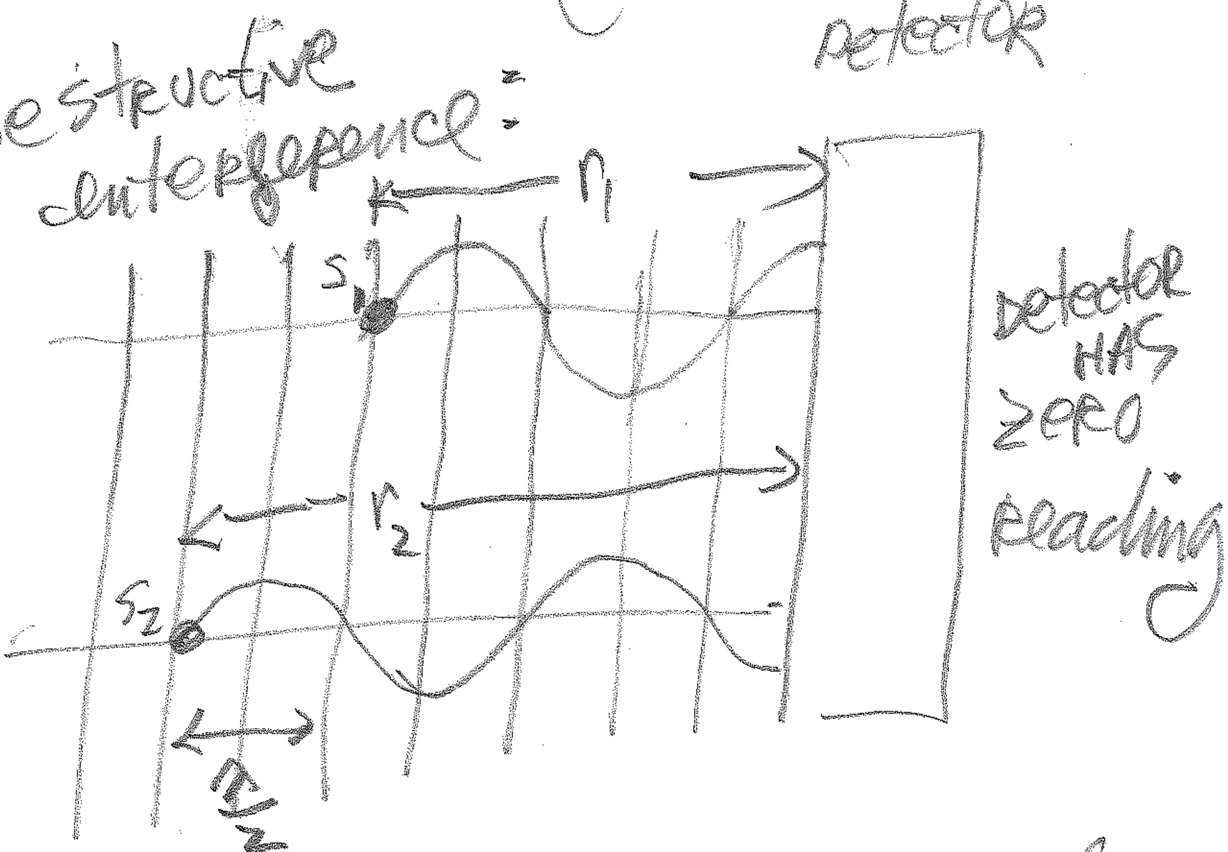
In general: $|r_2 - r_1| = n\lambda,$

$n = 0, 1, 2, 3, 4, \ldots$

IN PHASE

(13)

Destructive interference:



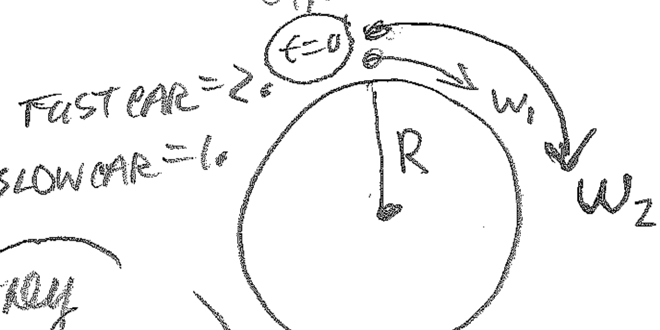
$$r_2 - r_1 = \frac{\lambda}{2} \text{ ; in general}$$

$$|r_2 - r_1| = (2n+1)\cdot\frac{\lambda}{2}, \; n = 0, 1, 2, 3, 4 \ldots$$

Beats

analogy:

4A problem 2 cars traveling at 2 different frequencies around a circular track of radius R.



FAST CAR MAKES 1 revolution before being able to pass by (catch up to) SLOW CAR.

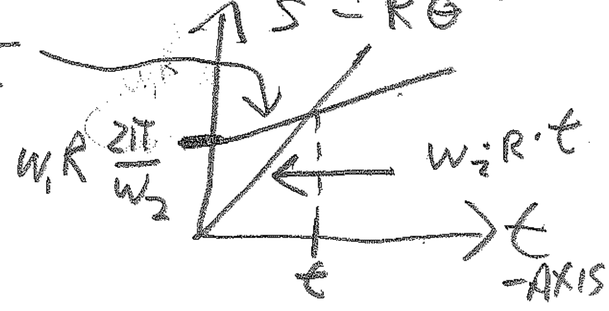
They start at $t=0$

TOTAL TIME TO catch up is $\frac{2\pi}{w_2} + \frac{2\pi w_1}{w_2(w_2 - w_1)}$. Here's a

proof: (A) to complete one revolution has time $\frac{2\pi}{w_2}$; (B) to catch up after 1 revolution solve:

$$w_2 \cdot R \cdot t = w_1 \cdot R \cdot \frac{2\pi}{w_2} + w_1 \cdot R \cdot t$$

$$t = \frac{2\pi w_1}{w_2(w_2 - w_1)}$$



Let's ADD and take reciprocal to get the "beat" frequency.

$$\frac{2\pi}{w_2} + \frac{2\pi w_1}{w_2 \cdot (w_2 - w_1)}$$

$$= \frac{2\pi \cdot (w_2 - w_1) + 2\pi w_1}{w_2 \cdot (w_2 - w_1)}$$

$$= \frac{2\pi w_2}{w_2 \cdot (w_2 - w_1)} = \frac{2\pi}{(w_2 - w_1)}$$

= Beat period.

$\Longrightarrow$ Beat frequency $= \dfrac{w_2 - w_1}{2\pi}$

$$= \frac{w_2}{2\pi} - \frac{w_1}{2\pi} = \boxed{f_2 - f_1}$$

$= f_{beat}$